RANCHO SANTA ANA BOTANIC GARDEN
OF THE
NATIVE PLANTS OF CALIFORNIA

APRIL 11, 1945.

CALIFORNIA WILD TREE CROPS

by
Carl B. Wolf

1945

Santa Ana Cañon, Orange County, California
Established 1927 in Memory of
JOHN W. BIXBY

RANCHO SANTA ANA BOTANIC GARDEN

Dedication of Garden Foundation to the Board of Trustees for the Rancho Santa Ana Botanic Garden of the Native Plants of California:

"THE NATURE, OBJECT AND PURPOSE OF THE INSTITUTION HEREBY FOUNDED AND TO BE MAINTAINED HEREUNDER.

ITS NATURE: A botanic garden of the native plants of California, herbarium and botanical library, containing living and/or preserved specimens of trees, plants and flowers native to California, and literature relating thereto.

ITS OBJECT: The preservation and improvement of the property now transferred and such property as may hereafter be transferred to the Trustees for those who not only wish to enjoy, but to study, assembled in one accessible locality, native California plants; and for the advancement of science and education with reference to plant life indigenous to the State of California.

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(b) To preserve the native California flora, try to replenish the depleted supply of some of the rarest plants which are rapidly being exterminated, and bring together in a comparatively small area as complete a collection of the rich store of native California plants as can be grown in this southern section of the state, thereby promoting the general welfare of the people of the state by providing the means for encouraging and carrying on the above mentioned activities in said state and by doing such other things as may be necessary and desirable to carry out the objects hereof."

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CALIFORNIA WILD TREE CROPS

THEIR CROP PRODUCTION
and
POSSIBLE UTILIZATION

by
Carl B. Wolf

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RANCHO SANTA ANA BOTANIC GARDEN

CONTENTS

	Page
Introduction	1
Review of Literature	3
The Joshua Tree	5
Botanical History and Characteristics	5
Distribution	5
Crop Production	7
Threshing Operations	11
Keeping Qualities of the Ground Pods and Seeds	11
Analyses	13
Summary of Information Pertaining to Joshua Trees and Their Fruits	15
The Oaks	19
General Discussion	19
The Blue or Douglas Oak	23
The Roble or Valley Oak	26
Field Work	26
Processing and Storing	27
The Kellogg Oak	31
Processing	33
Feed Values	33
The Coast Live Oak	35
Processing	37
The Garry or Oregon Oak	45
The Golden-Cup or Canyon Oak	49
The Tan-Bark-Oak	51
The California Buckeye	55
Field Studies and Harvesting	56
Drying and Processing	57
Feed Values	58
Conclusions	60
Table 1—Analyses of Important California Wild Tree Crops	62
Table 2—Moisture Determinations on Some Stored Seeds	64
Table 3—Percentages of Meats and Hulls Based on Hand-Hulled Samples	65
Table 4—Oil Analyses	67
Summary	68
Index	69

ILLUSTRATIONS

Figure		Page
1.	Joshua Tree Forest near Hesperia, San Bernardino County	6
2.	A Joshua Tree in the Kingston Mountains, San Bernardino County	8
3.	A cluster of Joshua Tree fruits from the Kingston Mountains, San Bernardino County	10
4.	A cluster of Joshua Tree fruits from Hesperia, San Bernardino County	12
5.	Joshua Tree fruits and seeds	14
6.	A Mojave Yucca in fruit in the Kingston Mountains, San Bernardino County	18
7.	Acorns of several oaks	20
8.	Acorns of several oaks	22
9.	Blue Oaks in the Sierra Nevada foothills near Chinese Camp, Tuolumne County	24
10.	The Sir Joseph Hooker Oak, near Chico, Butte County	28
11.	Kellogg Oaks in the Sierra Nevada foothills	32
12.	Fresh Acorns of the Kellogg Oak in the San Bernardino Mountains	34
13.	Coast Live Oaks at Orange County Park, Orange County	36
14.	Coast Live Oaks at Orange County Park, Orange County	38
15.	Acorns of the Coast Live Oak on the ground at Orange County Park, Orange County	40
16.	Close-up of acorns of the Coast Live Oak as covering the ground at Orange County Park, Orange County	41
17.	Pile of raked up acorns of the Coast Live Oak at Orange County Park, Orange County	42
18.	Freshly picked acorns of *Quercus Garryana semota* at Pineridge, Fresno County	46
19.	Golden-Cup Oak at Pine Grove, Amador County	48
20.	Freshly picked acorns of the Golden-Cup Oak at Pineridge, Fresno County	50
21.	Tan-Bark-Oaks in southern Humboldt County	52
22.	California Buckeye in full bloom at Pine Grove, Amador County	54
23.	A large California Buckeye in fruit at Menlo Park, San Mateo County	56
24.	Freshly harvested California Buckeye fruits at Valley Springs, Calaveras County	58
25.	Dried and partially dried fruits of the California Buckeye	59

INTRODUCTION

Although the native plant population of California numbers around 6,000 species, comparatively few of these yield products which have been commercially utilized on a large scale except as extremely valuable sources of lumber and for the grazing of livestock. There are, however, a number of plants which produce such enormous crops of fruits or seeds that it has seemed desirable to explore the possibilities of making use of these products. For many years we have been carrying on extensive field work throughout California and have more than once been greatly impressed by the truly astronomical amounts of fruiting materials that some of these widespread and abundant species produce in certain seasons. Our attention was also directed to this problem early in 1943 by Professor G. F. Ferris of Stanford University, who suggested that we at Rancho Santa Ana Botanic Garden ought to investigate the possibilities of making some good use of the acorn crops of California. Shortly thereafter, it was concluded that this could well be undertaken by the Garden, and preliminary studies were begun to determine if there were other native plants which also produced sufficiently large crops of fruits or seeds to warrant their utilization. As a result, it was concluded that the fruits of the Joshua Tree (*Yucca brevifolia* and its variety *Jaegeriana*) and the enormous seeds of the California Buckeye (*Aesculus californica*) were also often produced in such large quantities that they, too, should be included along with investigation of the acorns. Perhaps, additional plants will be given consideration at a later date, but the above mentioned kinds appeared to offer the most promise of yielding products in sufficient quantities to be of commercial interest. Certain other trees of California bear fruits or seeds of value, but these are for the most part only of minor interest in this state, although the same or related species may be rather valuable in other regions. The most important of these are: The Piñon Pines (*Pinus monophylla* and *P. quadrifolia*) for their nuts; The Digger Pine (*Pinus Sabiniana*) and the Sugar Pine (*Pinus Lambertiana*) also for their nuts; the Black Walnuts (*Juglans californica* and *J. Hindsii*) for their nuts; the Chinquapin (*Castanopsis chrysophylla*) for its chestnut-like nuts; the Hazel Nuts (*Corylus rostrata* vars. *californica* and *Traceyi*) for their nuts which are very similar to filberts; the Mesquites (*Prosopis chilensis* and *P. pubescens*) for their pods which are important sources of stock feed in the arid southwest, but are of minor importance in California; and the Western Choke-Cherry (*Prunus demissa*) for its fruits which make fine preserves, jellies and syrups.

Preliminary studies begun in 1943 and still being continued have resulted in our obtaining considerable information about the above mentioned plants and their products. Although some of this has long been known, much of it is new; and, for this reason, we feel should be presented at this time, particularly because of the possibility that it might lead to the utilization of some of these plant products during the present war as well as under normal conditions.

The actual large scale utilization of these products may never be realized or may be postponed for many years, yet an awareness of the potential supply, probable values and possible usages is of considerable importance; for, after all, the plant resources of this country are not unlimited, and some materials which only yesterday were regarded as of no value are today the basis of great industries. For example, the skins and pulp of citrus fruits were largely wasted a few years ago, but now are dried and ground into a meal which has become an important supplement in the feeding of dairy cattle.

Additional studies on harvesting, processing, feeding and other phases of these wild crops will be necessary before they can be utilized to any great extent. Most such work lies outside the field of this Botanic Garden and can best be undertaken by agricultural experiment stations or by private individuals. However, it is hoped that the data presented in the present paper will serve as a guide in determining which of these various wild crops are worthy of further serious consideration.

I am indebted to a great many people who have contributed information or assistance in carrying on the present studies. In particular, I wish to thank the following: Dr. H. J. Webber, member of the Garden's Advisory Board, for his sound advice in planning the investigations and in reading the manuscript; Dr. W. L. Jepson, member of the Garden's Advisory Board and Chairman of the Editorial Committee, for his help in reading and criticizing the preliminary manuscript; Mr. W. F. Beedle, of the Geo. W. Gooch Laboratories, for his generosity in giving time on several occasions to discuss at length the analyses; Mr. Lyman Barlow, of the Buena Park Plant of the Glidden Company, who has shown a keen interest in the oils of the Joshua Tree and Coast Live Oak acorns, and who kindly arranged to have Mr. Waldo, their chemist, extract oil samples so that analyses could be made; and Mr. G. E. Price, manufacturer of bean threshers, of Santa Ana, California, who made preliminary threshing or cleaning tests on acorns.

REVIEW OF LITERATURE

Since the present studies were begun, a number of books and papers have come to hand which deal directly or indirectly with the problems under investigation. Considering the geographical as well as numerical abundance of certain of the wild crops, it is rather astonishing that a great deal more has not been written about them. The principal publishings which I have been able to examine are listed below in the order of their publication and are discussed briefly because of their bearing on the problems of utilization of wild food crops of California.

Dr. C. H. Merriam wrote an article entitled "The Acorn, a Possibly Neglected Source of Food" (National Geographic Magazine **34**: 129-137. 1918). The subject matter consists largely of an account of the uses to which the California Indians put the acorns, and several illustrations depict actual utilization of them. Merriam reports analyses of leached and unleached acorn flour made from the California Black Oak (*Quercus Kelloggii*) which are essentially in agreement with the analyses presented in this paper. He also presents an analysis of the California White Oak (*Quercus lobata*) showing 18.6 per cent fat. This is so far out of line with our findings for this species that there is reason to believe there was an error in the determination of species. Merriam mentions that the fruits of the California Buckeye were also treated by the Indians to be made edible but does not go into details as to how this was accomplished.

Professor M. E. Jaffa of the College of Agriculture of the University of California (Report of the Director, pp. 57-58. 1919) reported on experiments conducted with the fruits of the California Buckeye. His brief data are discussed under that section of this paper.

In 1929 J. Russell Smith, Professor of Economic Geography, Columbia University, wrote a 333 page book entitled "Tree Crops—a Permanent Agriculture" (Harcourt Brace and Company, New York). In this book Professor Smith voices a plea for the planting of tree crops such as the Chestnut, Carob, Locust, Mesquite, Persimmon and Oaks on hilly land so that the valuable top soil of America will not be washed away by improper tillage. Two chapters are given over to the oaks. Chapter XIII is entitled "A Corn Tree—The Oak as a Forage Crop". This and the following chapter present a wealth of data, some of which is referred to later in this paper. Chapter XIV is entitled "Some Bread and Butter Trees—The Acorn as Human Food". In this chapter Professor Smith suggests the possibility that man has in the past perhaps eaten more acorns than wheat, and that use of acorns for human food may again become popular. However, he emphasizes that the real object of his book is "to call attention to the excellence of acorns as a farm crop producing forage for pigs, sheep, goats, cows, horses, chickens, turkeys, ducks and pigeons". On page 305 Professor Smith makes a comparison of several food items with corn, and states that acorns yield 1400 pounds per acre in comparison to 1960 pounds for corn, and that it would require

2.12 acres of oaks to produce the equivalent calories of one acre of corn.

F. B. Morrison in his book "Feeds and Feeding" (Twentieth edition, 1943) gives incidental mention (p. 403) to the use of acorns as feed for stock. He lists (p. 976) the composition of whole Red Oak and White and Post Oak acorns. These analyses for Eastern species do not differ greatly from those of *Quercus Douglasii* and *Q. lobata.*

Dr. George S. Jamieson, in his book "Vegetable Fats and Oils" (page 30, Second Edition, 1943) reports experiments on the characteristics of the oils of several species of *Quercus.* In particular, he summarizes a paper by W. D. Hutchins (Oil and Soap **14**: 148. 1937) in which the oil of *Quercus palustris* was extracted in South Carolina. As collected, these acorns contained 24 per cent moisture and 13.4 per cent oil. Jamieson states: "The refined oil could be used for edible purposes."

Temperton has reported (Nature [London] **152** (3856): 345-346. 1943—see Biological Abstracts **18**: entry 6738. 1943) that "dry horse chestnuts compare favorably with barley in dry matter, protein and fiber content; but, due to a persistently bitter substance, were rejected by the poultry in every form and mixture offered".

Temperton has reported (Empire Journal of Experimental Agriculture **11** (43/44): 175-181. 1943—see Biological Abstracts **18**: entry 21982. 1943) that "it is safe to include ripe, ungerminated acorns as part of the rations for laying hens and ducks. When such material constituted up to 20 per cent of the daily food-intake of hens and ducks, no adverse effects on health and production resulted". He also reported adverse effects on hens and egg production when the ration was increased to 40 and 60 per cent. On the other hand, rations of 33⅓ and 50 per cent acorns fed to ducks neither harmed the birds nor decreased egg production. Complaints of discolored yolks due to acorns are regarded by Temperton as largely due to the birds eating germinated acorns.

Thomas R. King and Harold E. McClure have recently published an article entitled "Chemical Composition of Some American Wild Feedstuffs" (Journal of Agricultural Research **69**: 33-46. 1944). Their paper gives the composition of 120 wild materials, including about thirteen kinds of oaks from the eastern United States. These analyses are presented on a dry weight basis and show a great variation in percentages of constituents for whole acorns. Crude protein ranges from 5.61 to 15.71 per cent, carbohydrates (nitrogen-free extract) are from 41.07 to 72.93 per cent, and fats range from 3.34 to 22.99 per cent. These authors also point out the necessity for feeding tests to determine the real suitability of various feeds for livestock and mention that King and Titus (Poultry Science **22**: 56-60. 1943—see Biological Abstracts **17**: entry 11663. 1943) "found in experiments with growing chicks that acorns of the willow oak are a rich source of vitamin A, comparable with Alfalfa-leaf meal". They also mention that Olsen (Poultry Science **21**: 497-499. 1942—see Biological Abstracts **17**: entry 9127. 1943) had demonstrated "that when hens were fed diets containing 25 per cent of meat or hulls of the acorns of either the white or black oak, they produced eggs having yolks of an undesirable, greenish color".

THE JOSHUA TREE

FIGURES 1-5

The Joshua Tree is of considerable interest because of the tremendous numbers of individuals which occupy great portions of the Mojave Desert in California and the adjacent desert regions of Nevada, Utah and Arizona.

In the past there have been several attempts to commercialize certain products of the Joshua Tree. These were primarily concerned with the utilization of the peculiar spongy wood and ranged from the making of surgical splints to tree wrappers or protectors and paper pulp. Recently, garden supply houses have been selling small pots made from thin sheets of Yucca wood which, I presume, is from the Joshua Tree. All of these products involved the destruction of the trees, and because of the slowness of growth the stands would eventually be seriously depleted. On the other hand, a utilization of the fruits and seeds of the Joshua Tree would in no way endanger the stands and could be a permanent industry. However, as far as I have been able to determine, no serious attempt has ever been made to utilize these products, except for the limited amounts of seeds ground into meal for human use by the Indians, and their incidental consumption by livestock grazing in the areas where they grow.

The information which we have obtained regarding the Joshua Trees is summarized below.

BOTANICAL HISTORY AND CHARACTERISTICS

The Joshua Tree was first published as *Yucca Draconis* var. *arborescens* by Torrey in 1856. In 1892 Trelease proposed that it be given specific rank as *Yucca arborescens*, a name which was used rather commonly for many years. However, Engelmann, in 1871, had proposed the name *Yucca brevifolia* for this plant, which is now generally used.

Two forms of the Joshua Tree have been distinguished in recent years; and, to those who are familiar with them in the field, it is strange that they were not recognized much earlier. In California typical *Yucca brevifolia* is largely confined to the western Mojave Desert. It forms a tree frequently over 30 feet in height and has leaves usually at least 12 inches long. The varietal form is characterized by a somewhat smaller growth habit and much shorter leaves. It is abundant on the eastern Mohave Desert and adjacent Nevada and is known either as variety *Jaegeriana*, a name proposed by Mrs. McKelvey in 1935, or as variety *Wolfei*, a name proposed by the late Marcus E. Jones slightly earlier. The former name will probably be regarded as the legitimate one because the latter was published in 1934 without a Latin diagnosis and was not distributed until 1935, after the deadline for accepting new taxonomic entities without such diagnoses.

DISTRIBUTION

Typical *Yucca brevifolia* is restricted to southwestern Utah, Arizona, Nevada and California. Comparatively large stands occur in western Arizona,

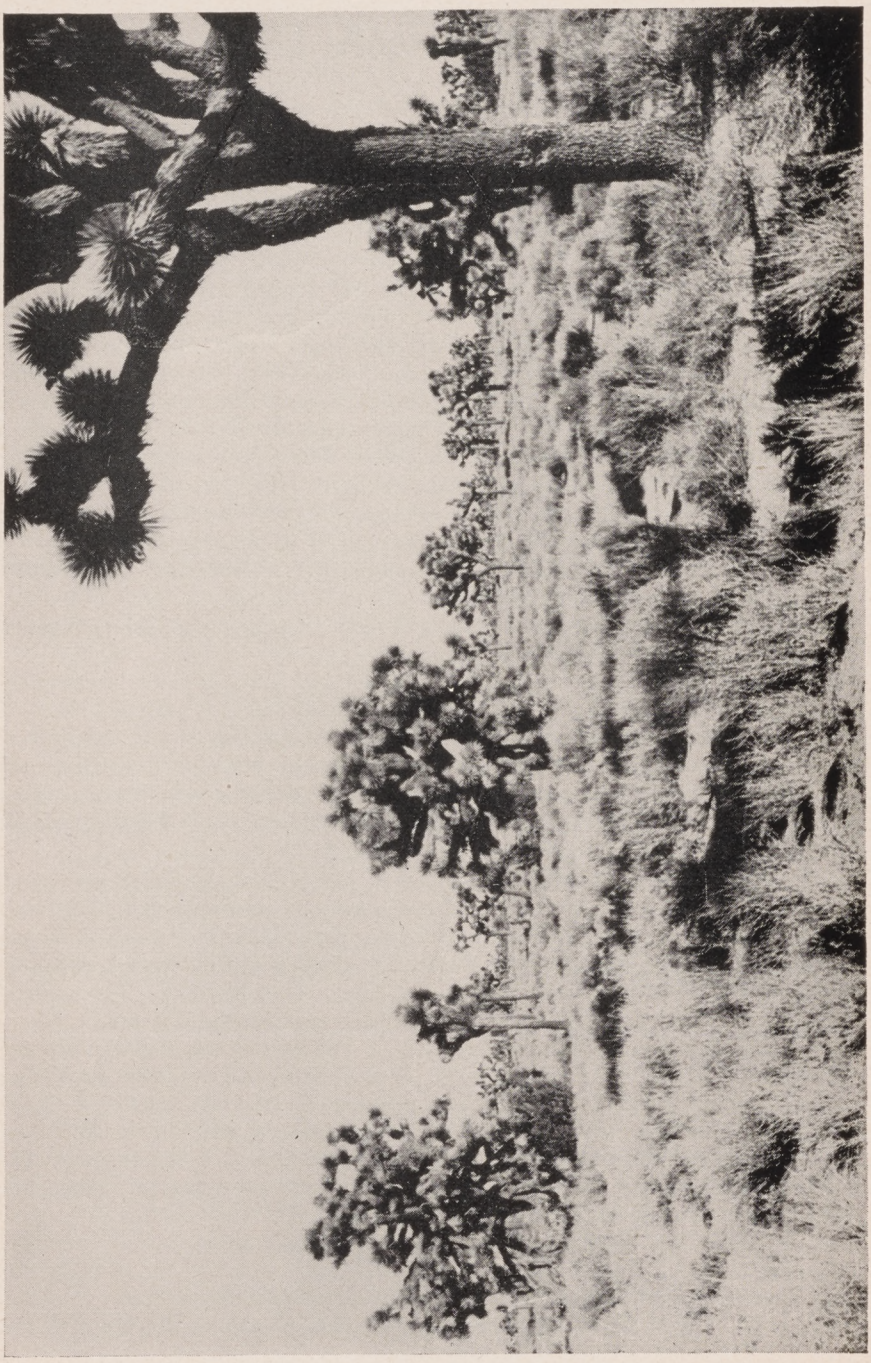

FIGURE 1—Explanation on opposite page.

but in Nevada and Utah it is largely replaced by variety *Jaegeriana*. In California it extends from Owens Valley south to the Cottonwood Mountains of Riverside County, but the large and important stands are those bordering the western portions of the Mojave Desert. These are largely at the bases of the desert slopes of the San Bernardino Mountains, particularly in the Hesperia region; the base of the San Gabriel Mountains, as at Palmdale, and extending west over much of Antelope Valley. There are also extensive stands along the east slopes of the Tehachapi Mountains, especially near Mojave, and in the vicinity of Walker Pass. These main areas constitute a desert forest covering several hundred square miles, most of which is readily accessible.

Yucca brevifolia var. *Jaegeriana* occurrs in southwestern Utah, southern Nevada, the extreme northwestern corner of Arizona, and on the eastern Mojave Desert of California. The truly extensive stands are confined to California and adjacent Nevada. Probably the most important areas occupied by this variety in Nevada extend to the southeast and southwest of the little mining town of Searchlight, the latter being essentially a continuation of those in adjacent California. In California the main distribution is from the Kingston Mountains southward to the Providence Mountains and westward to Yucca Pass a short distance east of Baker. Within this area, the most important stands lie in the vicinity of Cima, a small station on the Union Pacific Railroad, and in Lanfair Valley which lies adjacent to the Nevada border and south and east of the New York Mountains. The California and Nevada stands of variety *Jaegeriana* cover well over 1,000 square miles, over a large part of which an ordinary truck can be driven despite the lack of many roads.

We estimate that the total areas occupied by *Yucca brevifolia* and var. *Jaegeriana* in California and southwestern Nevada amount to at least 1500 square miles, a sizeable figure to be seriously considered in estimating the probable amounts of fruits produced.

Crop Production

My observations on the Joshua Tree extend back to the summers of 1922 and 1923 when I hunted jack rabbits in the Joshua Tree forests of the western Antelope Valley near Neenach. Since then I have had the opportunity of studying Joshua Trees in the field nearly every year. Seasons of large crops apparently occur at intervals of about three years. There were good crops in 1932, 1935, (I believe in 1937) and again in 1943 and perhaps one of the years between 1937 and 1943. I did not visit the eastern Mojave Desert in 1944, but on the western portion there was no crop in 1944.

Ordinarily, the Joshua Trees flower in March and April. Thereafter, the fruits (capsules) enlarge rapidly and reach their greatest size in May and June, at which time they are sometimes 4 inches long by 2 inches in

FIGURE 1—Joshua Trees (*Yucca brevifolia*) in the vicinity of Hesperia, western Mojave Desert, San Barnardino County, California. The open, park-like spacing of the trees is typical of the region and substantiates the statement in the text that trucks or tractors would have no difficulty in driving through such areas for harvesting operations. This photo was taken January 24, 1945, at which time some clusters of fruits produced in 1943 were still on the trees and contained good seeds, although the pod material was mostly worm-eaten and decayed.

FIGURE 2—Typical tree of *Yucca brevifolia Jaegeriana* in the southern portion of the Kingston Mountains, San Bernardino County, California. Photo, October 8, 1935. This tree stood about 13 feet high. Because of the smaller size of trees of variety *Jaegeriana*, it was thought that harvesting operations would be simpler than for its much larger relative *Y. brevifolia*. The low Yuccas in the background are specimens of the Mojave Yucca (*Yucca schidigera*).

diameter. The seeds are not mature until July or August. Gradually the somewhat fleshy fruit dries so that long before it drops from the tree it shrinks considerably and is much smaller than early in the season. We have collected mature fruits and seeds of *Y. brevifolia* in the Hesperia region on August 11, 1932, and of var. *Jaegeriana* from the Kingston Mountains on October 8, 1935. In both instances, none of the fruits had yet fallen from the trees. However, on October 27, 28 and 29, 1943, we found that at least 50 per cent of the crop of *Y. brevifolia* in the Victorville region had already dropped and a like amount of var *Jaegeriana* in the Kingston Mountains and the Cima region. Thus, it would appear that harvesting operations, with allowance for seasonal as well as regional variations, could begin early in August and extend to early October. The Victorville and Hesperia regions were visited again on February 17, 1944, at which time it was found that many fruits still hung on the trees; and, in some instances, nearly all the fruits of a cluster were still in place. Examination of the capsules showed that the seeds were in good condition, but that the starchy pod material had deteriorated considerably

The fruits of the two Joshua Trees are so similar that we decided to confine our field studies in the fall of 1943 to the var. *Jaegeriana* for several reasons. The first of these was because of the smaller size of the individuals which would enable us to pick the fruits more easily. The second was because the stands of this variety were so dense and so extensive that we could readily make test picks at numerous localities and thus gain a fair idea of the variation in production and the problems involved in harvesting. The third, and perhaps most important consideration, was that a very large part of the stands of this variety grew on Federal land which would be a decided advantage in negotiating for harvesting privileges should it later be found feasible to begin commercial harvesting. However, these apparent advantages would probably be offset by the remoteness of the area in contrast to the accessibility of the California stands of *Y. brevifolia*. Possibly, the region around Hesperia would be most ideal from all standpoints for the first large-scale experimental harvesting operations.

On October 27, 1943, a trip was made to the Mojave Desert to make a test picking of var. *Jaegeriana*. Beginning at the south base of the Kingston Mountains, we journeyed south to Valley Wells but concluded that over most of that area the Joshua Trees were too scattered to warrant their being harvested. From Valley Wells we drove south to Cima through mile after mile of Joshua Trees. At Kessler Spring we obtained permission to collect Joshua Tree fruits from Mr. Graham, owner of a large cattle ranch and lessee of thousands of acres of Federal land in that area.

Mr. Graham informed us that we were too late to obtain a true estimate of the crop since a fair percentage of the fruits had fallen and been eaten by his cattle. He told us that cattle were very fond of these fruits, but sometimes ate so many that scours resulted (possibly because of their high oil content). He also told us that early rains sometimes caused the fruits to sour while still on the trees. This would seriously lower the value of the crop but would not cause the seeds to spoil.

Between Kessler Spring and Cima, the Joshua Tree forest is so dense that in many places it appears like an irregularly planted orchard. A number of side roads radiate out from around Cima, but the nature of the ground is such that we were able to drive almost anywhere among the Joshua Trees without difficulty and did not have to follow the roads.

Never having harvested more than a few fruits of the Joshua Tree before, except for botanical specimens and for propagation, I was uncertain as to just how they could best be obtained. I had taken with me an ordinary jointed long arm pruner which could be extended to 20 feet, the blade of which was operated by pulling a rope. With this I had expected to be able to cut the large clusters of fruits with a single operation and to be able to pick them up intact from the ground. I soon found that because of the spreading bracts and leaves surrounding the base of each fruiting cluster that a much larger or different type cutter would be required, and that harvesting operations should have been earlier so that the clusters of fruits would not shatter in dropping to the ground. This necessitated using the pruner as a knocking

FIGURE 3—*Yucca brevifolia Jaegeriana*. Cluster of fruits from same tree as in Figure 2, in south end of Kingston Mountains, San Bernardino County, California. Photo, October 8, 1935. The reflexed leaves just back of the fruits and the thick branch illustrate the need for a special cutting tool to harvest these clusters.

pole and picking up the fruits individually—a process which proved to be rather slow.

In order to gain as much information as possible about the problems of harvesting Joshua Tree fruits and the variation in their fruiting habits, I made my collections over a great many square miles, seldom taking more than part of the fruits from more than three or four trees in any one spot. However, even by this method and working entirely alone, in eight hours of work I succeeded in obtaining about 450 pounds of pods which in volume amounted to about 40 cubic feet.

There proved to be considerable variation in the size of the pods as well as in the number per cluster and the number of clusters per tree. Individual pods varied from 2½ to over 4 inches long and were usually a little less than one-half their length in diameter. The number of fruits in a cluster ranged from 10 or 15 to over 100, the average being about 25 or 30. Small trees with only a few branches frequently produced only two or three clusters of fruits, while some of the well-branched large specimens had as many as 50 clusters. Individual fruits when thoroughly air-dried varied in weight from one-half to two ounces, so that a large tree with 50 large clusters might produce nearly 200 pounds of fruits, but the average per tree would be from 20 to 50 pounds.

Variation in density of the stands of Joshua Trees is so great that it is almost an impossibility to present any adequate figures as to the potential crop for the entire California-Nevada region. In some places trees of fruiting size would average 40 to 50 per acre, while in others they would hardly average one tree per acre. Obviously, any harvesting operations would be confined to the densest stands and to trees with large clusters of fruits. However, I believe, that there are several hundred square miles of Joshua Trees which are sufficiently thick to produce over 500 pounds of fruits per acre. With proper equipment for cutting the fruiting clusters from the trees and either canvasses or broad truck or trailer beds for them to drop into, it would be possible for crews of men working in the field to average about 1,000 pounds of fruits per man per day.

Threshing Operations

The approximately 450 pounds of Joshua Tree fruits which we brought back to the Garden were processed or threshed by hand. The dry fruits were crushed on a cement floor by being spread out in layers and pounded with an ordinary iron cement tamper. After this crushing the seeds were separated from the pod material by screening. Finally, the seeds were run through a small fanning mill which gave almost clean seed. As a result of these crude but effective operations, we obtained 210 pounds of crushed and powdered pods and 211 pounds of reasonably clean seeds.

We believe that the threshing of the Joshua Tree pods could be readily accomplished on a large scale, and that either existing threshers could do the work or, with slight modifications, could be made to do it.

Keeping Qualities of the Ground Pods and Seeds

It has now been over a year since the fruits were crushed and the finely

FIGURE 4—Cluster of fruits of *Yucca brevifolia*. This was collected near Hesperia, San Bernardino County, California, and was part of the bumper crop of 1943. Photo taken January, 1945. Many large Joshua Trees produce over fifty such large clusters of fruits in a good crop year. This one cluster weighed 5 pounds, 6 ounces and contained over 100 fruits from which about one pint of oil could be extracted.

mashed capsules were separated from the seeds. Possibly because of the low moisture content (7.60 per cent for the ground pods and 5.90 per cent for the seeds), both the pod material and the seeds have offered no problems in storage or in keeping qualities, features which would be important in large scale operations. These materials have not since been tested for their moisture content, but are probably higher because of the moist air of the coastal area where they have been in storage.

Analyses

Three separate analyses as to the composition of the Joshua Tree fruits were made (see Table 1), namely: the entire pods, the pure seeds, and the ground pods less seeds. These analyses were enlightening in that they showed that not only were the seeds high in oil and fair in proteins, but that the pod material was also a fair feed material and compares very favorably with dried orange peel as listed by Morrison (Feeds and Feeding, p. 986), which has 5.8 per cent protein, 0.7 per cent fat, 10.6 per cent fiber, and 64.7 per cent nitrogen-free extract. Thus, a comparison shows that Joshua Tree pods are slightly higher in protein and fats; contain about 50 per cent more fiber and 5 to 6 per cent less carbohydrates.

The analysis of the Joshua Tree seeds showed such a high percentage of fat (34.40 per cent) that it appeared that here was a potential source of a perhaps valuable vegetable oil. For comparative purposes, flaxseed has 36.4 per cent oil, cottonseed 21 to 23 per cent, and soybeans about 18 per cent. On the basis of it being possible to extract about 600 pounds of oil from a ton of Joshua Tree seeds, there would be left a residue or meal amounting to around 1,400 pounds which would have an analysis somewhat as follows as compared with wheat bran:

	Joshua Tree Seed Meal	Wheat Bran
Moisture	9 per cent	
Crude Protein	15.5 "	15.8 per cent
Fat	5 "	5 "
Fiber	15 "	9.5 "
Nitrogen-Free Extract (Carbohydrates)	53 "	54.3 "
Ash	2.5 "	6.0 "

This Joshua Tree seed meal is not greatly different in its main features from wheat bran, except that the fiber content is considerably higher, but there are many other concentrates which have even a higher fiber content. Just where and how the Joshua pod meal and seed meal would be used in the feeding of livestock can not be determined at the present time on the basis of analyses alone, but it is known that cattle relish the whole pods, and that the seeds and seed meal are not at all disagreeable when eaten raw by humans. On the basis of the above estimate, 100 pounds of Joshua Tree seed meal would contain about 73 pounds of proteins, fats and carbohydrates and be worth $2.01 per cwt.

The analysis of the Joshua Tree oil was made possible through the cooperation of Mr. Lyman Barlow of the Buena Park Plant of the Glidden

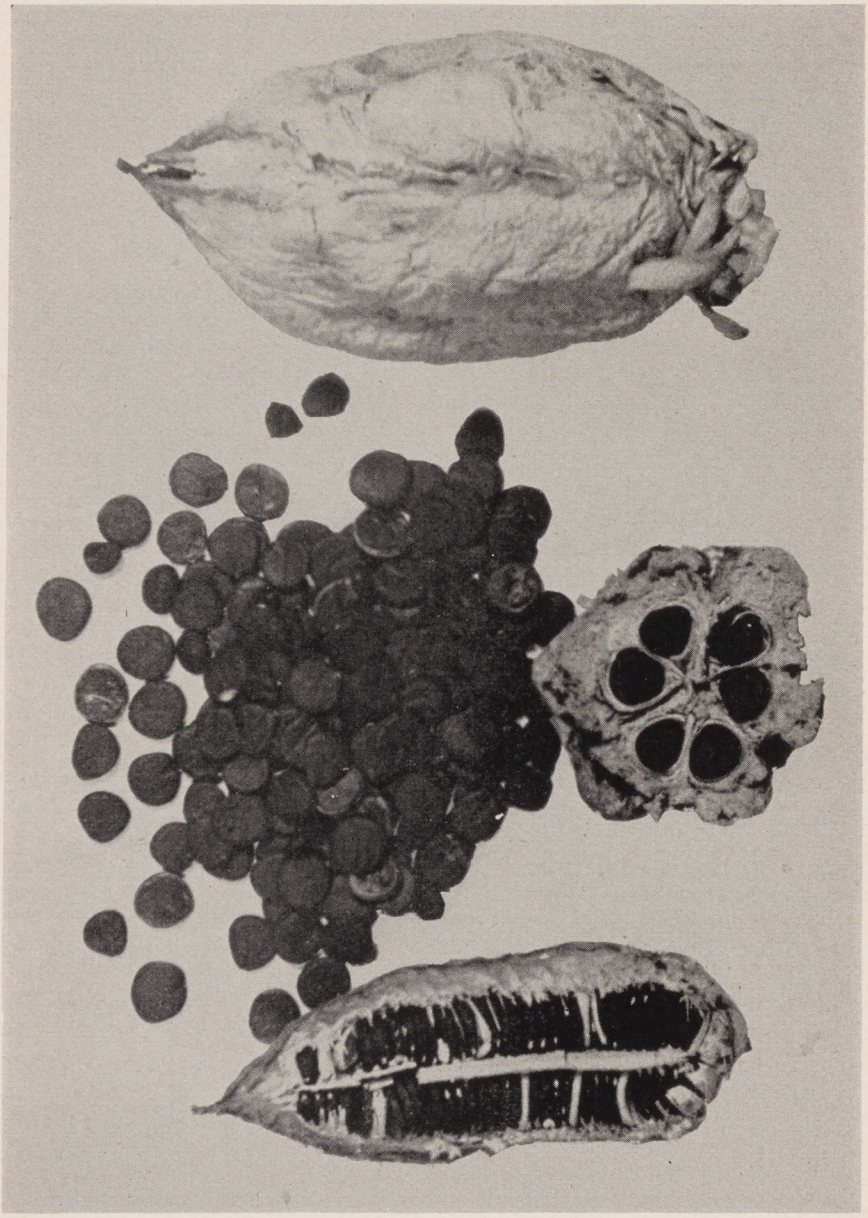

FIGURE 5—*Yucca brevifolia.* Fruits and seeds of 1943 crop from near Hesperia, San Bernardino County, California. Photo taken January, 1945. The whole fruit at the top of the picture measured slightly over four inches long. The seeds were taken from a similar capsule; weighed 18.5 grams and totaled 161 good seeds. The cross section of the capsule illustrates the proportions of pod material and the six rows of black seeds. The longitudinal one-third section of a fruit shows the normal number of sterile (white) seeds.

Company who had Mr. Waldo, their chemist, press out a few ounces of oil in a small hand press for analysis by the Gooch Laboratories.

Joshua Tree oil is a clear, light yellow oil, practically tasteless and odorless. Its iodine number of 120.3 indicates that it is a semi-drying oil which along with its other characteristics indicates that it may be found to have some value for other uses than merely as an edible oil for salads, shortening, etc. (See Table 4).

Several pounds of Joshua Tree seeds were furnished Mr. Barlow for investigation by the Glidden Company's research laboratory in San Francisco as to the characteristics of the oil. He later reported that, in their opinion, the Joshua Tree oil had no special or peculiar properties which would make it particularly valuable other than as a high grade edible oil.

The value of a ton of Joshua Tree pods may be roughly estimated as follows:

1000 pounds of pod meal at $1.88 cwt.	$18.80
300 pounds of oil at 14 cents a pound	42.00
700 pounds of seed meal at $2.01 cwt.	14.07
Total	$74.87

The above values for meal are obtained by comparing with Pacific Coast Barley at $2.25 per cwt. and computing the total food materials.[1] In the case of seed meal, the value is probably too low since it contains nearly twice as much protein as barley. The value of the oil is based on the current price for cottonseed oil.

On the above basis (barley at $2.25 per cwt.), the 100 pounds of whole pods as harvested would contain 76 pounds of proteins, fats and carbohydrates and would be worth $2.10 per cwt. The pods, less the seeds, have 68 pounds of proteins, fats and carbohydrates per 100 pounds and would be worth $1.88 per cwt.

In view of the apparently valuable properties of the pods and seeds of the Joshua Tree, it would also seem that the Mojave Yucca (*Yucca schidigera*) might also be investigated. Its leathery pods are relished by stock; its seeds are scarcely distinguishable from those of the Joshua Tree and are apparently equally oily. The Mojave Yucca is even more widespread than the Joshua Tree and might prove to be as valuable. Herbarium specimens of pods with mature seeds over 10 years old have kept perfectly in glass bottles, and the oil of the seeds has not turned rancid.

Summary of Information Pertaining to Joshua Trees and Their Fruits

1). Previous attempts to make use of the Joshua Tree or its products have included the use of the wood for surgical splints, tree wrappers, and paper pulp, and use of the fruits by the Indians for food, and their incidental consumption by livestock on the lands where they grow.

[1]With Pacific Coast Barley at $2.25 per cwt. its proteins, fats and carbohydrates total 81.6 pounds or are worth $2.76 per cwt. Multiplying the total proteins, fats and carbohydrates by this figure, gives an estimated feed value which disregards digestible nutrients and does not take into account different values for proteins, fats, and carbohydrates. Nevertheless, as a rough estimate, this method offers a reasonable basis of comparison. Anyone desiring to make computations on a more balanced basis can readily do so by means of the several analyses included in this paper.

2). The two forms of the Joshua Tree are known as *Yucca brevifolia* and variety *Jaegeriana*. The former is a larger tree and in California is mainly confined to the western Mojave Desert. The latter is much smaller and is restricted almost exclusively to the eastern Mojave Desert and adjacent Nevada. Both varieties produce fruits essentially alike.

3). The most important stands of *Yucca brevifolia* are in the Hesperia region and in the vicinity of Palmdale. The best stands of variety *Jaegeriana* are in the Cima area and Lanfair Valley, both in San Bernardino County, but excellent stands also occur in southwestern Nevada in the Searchlight area. Altogether, these probably exceed 1500 square miles of reasonably dense stands.

4). Crops of Joshua Tree fruits are produced at irregular intervals but appear to average once every three years. These ripen about the middle of August but do not begin to drop seriously until late in September, and a large part of the crop remains on the trees until well into October and even into the following February.

5). Field studies during 1943 were conducted in the Cima area on variety *Jaegeriana* late in October, at which time a test picking of 450 pounds of fruits was made. This was somewhat late to obtain ideal data, but resulted in our reaching the conclusion that with a little special equipment to cut the clusters of fruits that 1,000 pounds of pods could be harvested per day per man under commercial conditions.

6). There is great variation in fruit production, ranging from as little as 10 pounds per tree to a maximum of about 200 pounds, the average probably being around 20 pounds per tree. Our observations would indicate that by confining harvesting operations to the better stands that 500 to 1,000 pounds of fruits could be obtained per acre, and that this amount could be obtained from at least several hundred square miles of the total areas occupied by the trees.

7). Approximately 450 pounds of fruits were threshed by hand and produced 210 pounds of finely powdered pod material and 211 pounds of seeds. It appears that no serious problems should arise in threshing these by machinery, and that both the seeds and ground pods are easily stored without spoilage.

8). Analyses of the whole pods, seeds and ground pod material disclosed that the seeds contained over 34 per cent oil and a fair amount of protein, and that the ground pods were a fair feed material closely approximating dried orange peel in its analysis.

9). From the seeds it appears that about 600 pounds of oil per ton could be extracted by means of ordinary oil expellers leaving a residue or meal roughly equivalent to wheat bran in its composition.

10). Joshua Tree oil appears to be a fine quality light oil, pleasant in taste and with characteristics which might prove to warrant its usage for even more important purposes than merely as another edible oil.

11). Based on present values of feeds and oils, a ton of Joshua Tree pods would yield products estimated to be worth $74.87.

12). The Mojave Yucca (*Yucca schidigera*), a widespread species of the deserts of California, Nevada and Arizona, also produces fruits readily eaten by stock and whose black seeds appear to be as oily as those of the Joshua Trees. Any program of utilization of the latter should also give serious consideration to the former. (Figure 6)

FIGURE 6—Fruiting plant of the Mojave Yucca (*Yucca schidigera*) in the southern portion of the Kingston Mountains, San Bernardino County, California. Photo, October 8, 1935. Leaves of the Mojave Yucca produce a fiber useful for rope. The fruits are relished by stock, and the seeds are very similar to those of the Joshua Tree. Harvesting of these clusters of fruits would be easier than for those of the Joshua Tree since the plants are seldom over 8 feet high. Any program of utilization of the Joshua Tree fruits should give serious consideration to this species which is even more widespread in distribution.

THE OAKS

General Discussion

California not only has a large number of oaks, but some of these grow over such large areas and in such great profusion that there is hardly any region save the desert valleys where they are not found. Periodically these trees and shrubs produce crops of fruits, so familiar to all as acorns.

A list of the wild animals, including birds, mammals and insects which utilize acorns as important sources of foods would be a long one. To this would also be added domestic livestock which greedily devour vast quantities of acorns. Formerly, the California Indians depended upon acorns for their major source of carbohydrates, and even today it is not an uncommon sight to see Indian women picking up acorns to grind into meal for mush or bread in essentially the same way their ancestors did a few hundred years ago. In November, 1943, at North Fork, Madera County, I saw an old Indian woman gathering acorns of the Kellogg Oak; and, although I did not ask, I assumed they were for human food.

According to Dr. C. H. Merriam (The Acorn, a Possibly Neglected Source of Food, National Geographic Magazine **34**: 129. 1918), the Indian population of California numbered not less than 300,000 persons, and acorns constituted a principal item of their food. From this it can readily be seen that the total amount of acorns harvested, stored and utilized by the Indians must have been tremendous.

At present, the principal use to which acorns are put consists of allowing livestock (mainly cattle and hogs) to forage among oaks and pick up the acorns from beneath the trees or bushes. An advantage of this is that feed is obtained cheaply and at a time when other range products are scarce. The disadvantages are that in seasons of prolific crops of acorns only a small proportion of the total is eaten before the rains and insects spoil the remainder, and that excessive consumption of acorns produces "soft fat" in pigs and occasional digestive upsets in other animals because they are not a balanced ration. A few farmers in numerous parts of California go out in the fall and rake up truckloads of acorns for feeding stock, but this is an exception and amounts to only an infinitesimal percentage of the total crop.

Our interest in acorns goes back for a number of years but has been mainly as a source of propagation material for the Garden plantings. However, more than once while in the field we have been astonished at the size of the crops produced. One of the most vivid impressions in this regard was obtained in October, 1931, when we camped in the forest of Blue Oaks (*Quercus Douglasii*) a few miles from Redding, Shasta County. We had made camp after dark and had not observed the oaks particularly, but throughout the night the stillness was broken by the continuous dropping of acorns upon the hard dry clay soil and upon the roof of our car. The next morning we discovered that it was an impossibility to walk anywhere beneath these oaks without stepping on several acorns. A few years later (1934), we visited

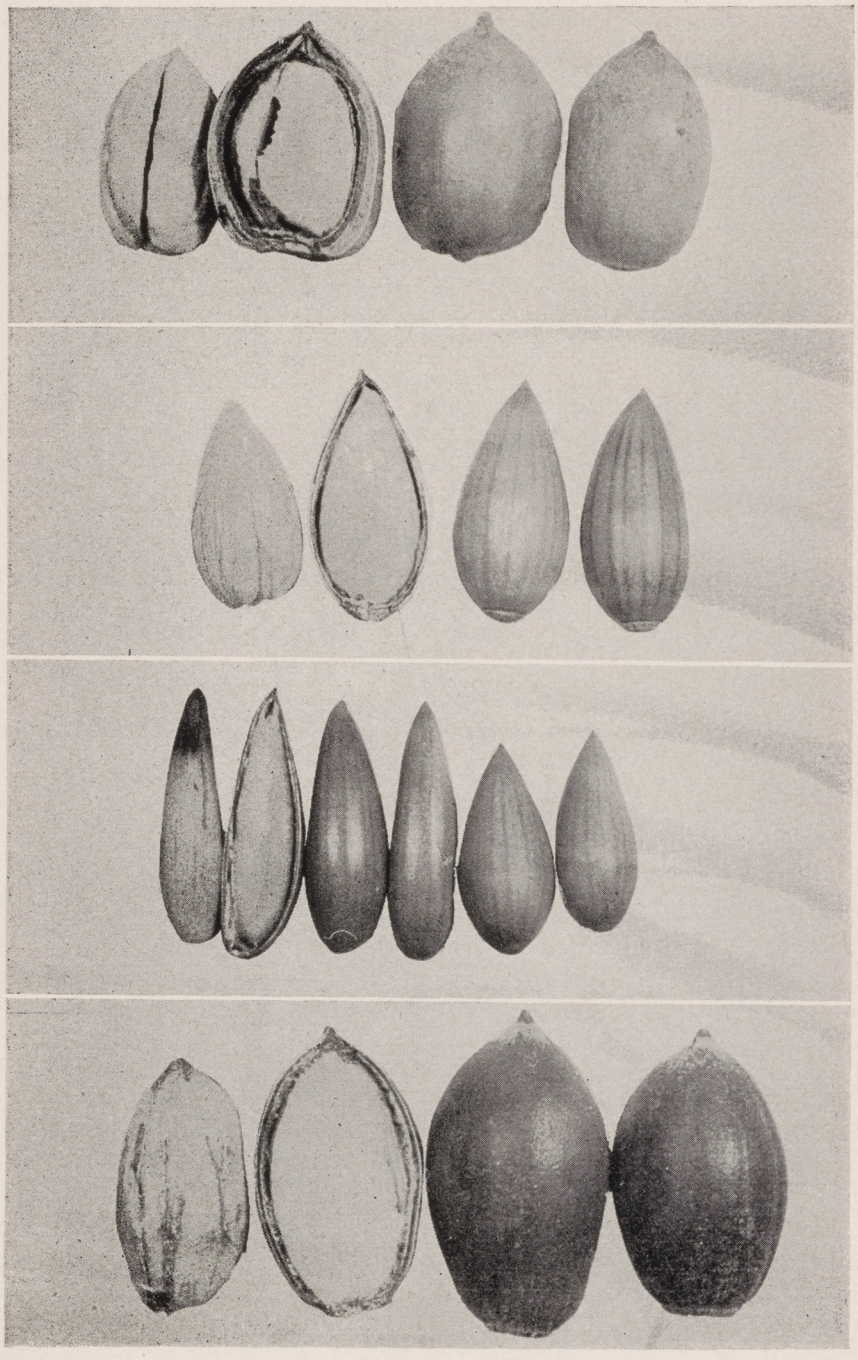

FIGURE 7—Explanation on opposite page.

the famous Sir Joseph Hooker Oak (a specimen of *Quercus lobata*) near Chico. The ground beneath this huge oak whose canopy covers around 15,000 square feet of ground was practically covered solidly with acorns. Although we made no estimate at the time as to the total crop on this tree, our more recent observations on other trees of this same species make it safe to assume that the total weight of acorns produced that year on this one oak must have been somewhere between a half a ton and a ton. On numerous other occasions, I have seen almost frantic gardeners on the lovely estates of the Peninsula south of San Francisco raking up wheelbarrow after wheelbarrow of acorns of the Coast Live Oak (*Quercus agrifolia*) and dumping them in an effort to rid their grounds of a crop which often presented a more serious fall problem in maintenance than the raking of leaves or mowing of lawns.

Of the nearly 20 kinds of oaks native to California, a number were ruled out in our preliminary plans for studying them as possible kinds which could be utilized by harvesting on a large scale. All of the shrubby species were eliminated from consideration as well as several rare tree kinds from which it was obvious that only limited amounts of acorns could be readily obtained. The Engelmann Oak (*Quercus Engelmannii*) of southern California was also considered of no merit because it seldom, if ever, produces prolific crops of acorns and because its acorns are very small. The Sierra Live Oak (*Quercus Wislizenii*), although widespread in both the Sierras and the Coast Ranges, generally does not occur in large stands in the Coast Ranges, while in the Sierras it is so frequently confined to the rougher areas of the foothills that its acorns would be difficult to harvest. Furthermore, they are usually very small in size. For these reasons, the Sierra Live Oak is of little interest as a commercial source of acorns.

The remaining California oaks which we tentatively decided were of importance as warranting investigation as sources of acorns in large quantities were: the Blue Oak (*Quercus Douglasii*), the Roble or Valley Oak (*Quercus lobata*), the Kellogg Oak (*Quercus Kelloggii*), and the Coast Live Oak (*Quercus agrifolia* and its variety *oxyadenia*). The Garry or Oregon Oak (*Quercus Garryana*) and the Golden Cup Oak (*Quercus chrysolepis*) were at first regarded as of little importance, but studies in 1944 indicated that in some areas these two produced acorns in sufficient amounts to be given consideration also. In addition, we included the Tan-Bark-Oak (*Lithocarpus densiflora*), which although of another genus produces typical oak acorns.

FIGURE 7—Acorns, all approximately natural size. Photos, January, 1945.

Top row. *Lithocarpus densiflora*. Note the thick shell of this species. Acorns are 1943 crop from Saratoga, Santa Cruz Mountains, California.

Second row. *Quercus agrifolia*. From a collection made at Orange County Park, Orange County, California, November 29, 1944.

Third row. *Quercus agrifolia oxyadenia*. From a 1943 collection made at Kitchen Creek, San Diego County, California. The differences in shape between the acorns of this variety and those of *Quercus agrifolia* are not constant; slender and fat acorns can be found in both sorts.

Bottom row. *Quercus Kelloggii*. From a 1944 collection made near Cuyamaca Lake, San Diego County, California.

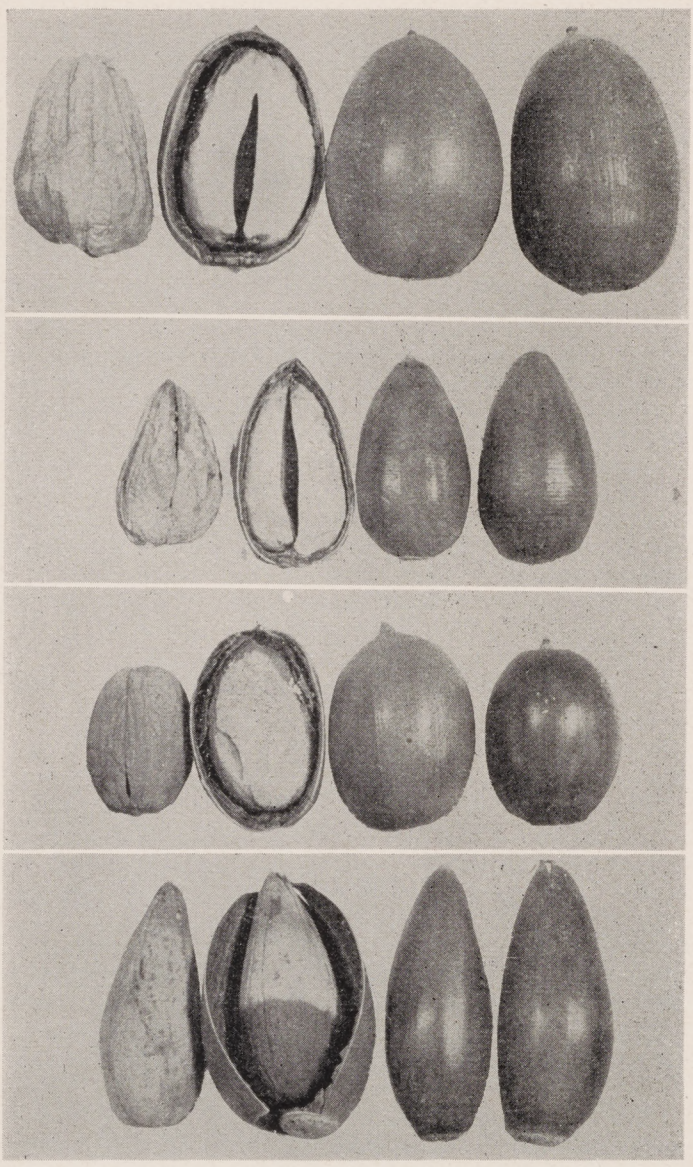

FIGURE 8—Acorns, all approximately natural size. Photos, January, 1945.

Top row. *Quercus chrysolepis*. From a 1944 collection made near Cuyamaca Lake, San Diego County. These are the heaviest acorns yet noted for any species in California, although those of *Quercus lobata* are often longer.

Second row. *Quercus Douglasii*. From a 1944 collection made near Red Bluff at the head of the Sacramento Valley, California.

Third row. *Quercus Garryana*. From a 1944 collection made near Weaverville, Trinity County, California.

Botton row. *Quercus lobata*. From a 1944 collection made near Clear Lake, Lake County, California. Note the split hull which is characteristic of this species. Some trees produce much larger acorns.

THE BLUE OR DOUGLAS OAK

Figures 8 & 9

Unfortunately, the Blue Oak (*Quercus Douglasii*) did not produce a crop of acorns in 1943 in the Sierra Nevada foothills from Madera County southward or in the Coast Ranges south of San Francisco. Woodbridge Metcalf, Extension Specialist in Forestry of the College of Agriculture of the University of California, reported to us that the trees of the Sacramento Valley had borne a good crop, but we received this information too late to make a collection.

The Blue Oak is, perhaps, the most abundant tree species of this genus in California and extends from the Tehachapi and Liebre Mountains northward in the Sierra Nevada foothills to north of Redding at the head of the Sacramento Valley. In some places it forms a band 15 to 20 miles in width. In the Coast Ranges it extends south from Redding to the Liebre Mountains, and in many places forms a much wider belt than in the Sierras. Altogether, this oak must occupy an area of at least 10,000 square miles, on many parts of which the trees are widely scattered, but there are also hundreds of square miles where they are thick enough to be called an oak forest. The trees are generally much smaller than the Valley Oak and do not produce as many acorns per tree.

Our observations in the fall of 1944 covered the main portions of the range of the Douglas Oak. In the South Coast Ranges, there was apparently no crop. In the Sonoma and Napa County areas, an occasional tree had produced a few acorns. In the Redding and Red Bluff areas at the head of the Sacramento Valley, an occasional tree had produced a heavy crop of acorns but most trees had none. In the Sierra Nevada foothills from Sacramento south to Kern County in the numerous spots where stands of this tree were examined, only an occasional one had borne more than a few pounds of acorns.

As mentioned above, the Blue Oaks over most of California produced few acorns in 1944. However, a few miles north of Red Bluff a tree with a rather heavy acorn production was located, and it serves to substantiate previous statements as to the tremendous amounts of acorns that are produced in California when this widespread oak bears a bumper crop. The tree studied was somewhat irregular in outline and was about 27 feet in height, 30 feet in spread and had a trunk diameter of about 20 inches. Beneath this tree the acorns lay rather thickly, and several measured tests showed that they averaged over 20 acorns per square foot. Since these acorns weigh about 4 or 5 to the ounce, it is estimated that this tree produced at least 160 pounds of acorns. There are many Blue Oaks of greater size, and my earlier observations lead me to believe that when bumper crops are produced that the acorns would be twice as abundant on the ground. However, in order to arrive at a reasonable estimate, let us use the above production of 20 acorns to the square foot beneath a tree. In some of the better stands of this oak, I estimate that the trees cover about fifty per cent of the total ground surface and, in a good season, would thus produce in excess of 5,000

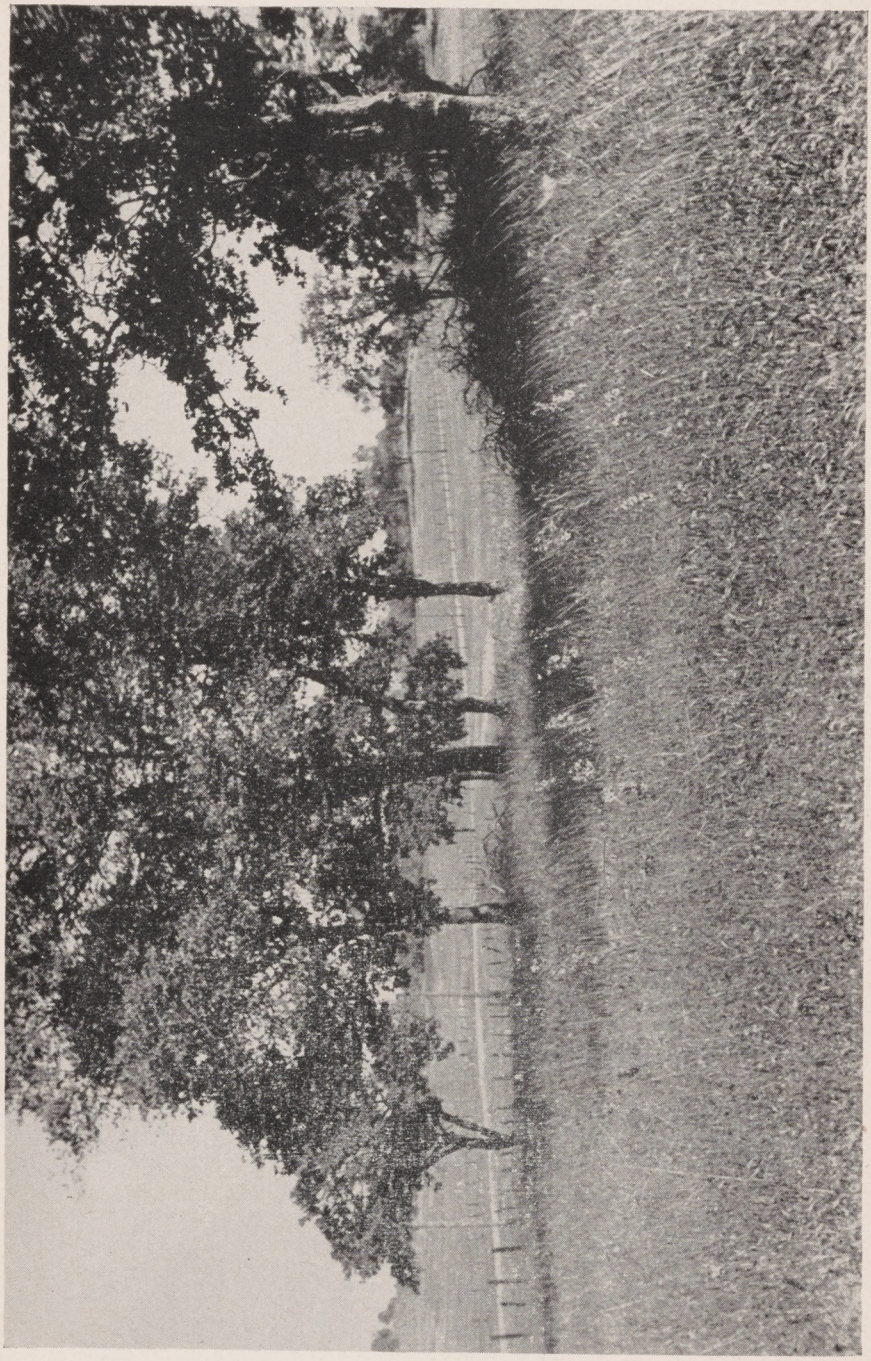

FIGURE 9.—Explanation on opposite page.

pounds of acorns per acre. On the other hand, there are several thousand square miles occupied by this oak where the density is probably not more than one tree per acre. It can thus be seen that in good acorn crop years this one species of oak alone might produce one million tons of acorns, although it is unlikely that all the regions of the state would have a large crop the same year. Probably a crop of 250,000 tons would be a safe and conservative estimate. As a direct basis of comparison, the average production of barley in California for the years 1926 to 1930 was 740,000 tons (University of California, College of Agriculture Bulletin **512**: 6. 1931). It can be readily seen that if the estimated crop production of this one oak is at all accurate, that it is a truly important source of feedstuff.

Since the areas where the Blue Oak grows are so largely the cattle ranges of the state, and since the acorns are produced at a time when other feeds are scarce, I believe that its acorns are probably the most extensively utilized of any tree oak of the state at present. In many of the rougher areas where this tree is native, I suspect that cattle or other livestock will continue to be the most efficient agency for harvesting its acorn crops, despite the fact that in years of great abundance a large portion is wasted.

The acorns of the Blue or Douglas Oak are very similar in their constituents to those of the Valley Oak but are slightly higher in fats and proteins. As harvested, 100 pounds would have nearly 58 pounds of proteins, fats and carbohydrates and be worth $1.60 (compared to barley at $2.25 per cwt.). When dried to an estimated 9 per cent moisture, 100 pounds would have 79 pounds of proteins, fats and carbohydrates and be worth $2.18 per cwt.

FIGURE 9—Blue Oaks (*Quercus Douglasii*) in the Sierra Nevada foothills near Chinese Camp, Tuolumne County, California, May 22, 1933. This species, along with the Digger Pine (*Pinus Sabiniana*) is characteristic of a broad belt of the Sierra Nevada foothills and the Coast Ranges. It is probably the most abundant tree oak in California, not only as to numbers, but also as to the geographic area it occupies.

THE ROBLE OR VALLEY OAK

Figures 8 & 10

The Roble or Valley Oak (*Quercus lobata*) is the outstanding oak of the interior valleys of California. It is found in rich soils of the valleys and foothills from the head of the Sacramento Valley to Los Angeles County. Stately trees with a height and spread of a hundred feet are common, and even in many fields long cultivated the owners have allowed these venerable monarchs to remain. Because of their large size, they are usually not close together, but there are many areas where they form vast park-like vistas. There are hundreds of square miles of these trees in Monterey County, especially in the Jolon region; in San Luis Obispo County around Paso Robles; on the Peninsula in the vicinity of Palo Alto; around Clear Lake, Lake County; Chico, Butte County; Fair Oaks, Sacramento County; and Visalia, Tulare County. The total geographic area occupied by this oak in California is nearly as great as that of the Blue Oak, but the individuals are fewer in number. However, because of the huge amount of acorns produced per tree, the crop is probably nearly as large.

Field Work

On October 2, 1943, I journeyed north to the San Joaquin Valley in search of an area where I might make a test collection of Valley Oak acorns. At Cutler Park, located on the St. Johns River a few miles northeast of Visalia, Tulare County, I found an ideal area and obtained permission to gather as many acorns as I desired.

I first tried raking up the acorns in small piles, but found that so many leaves and twigs as well as considerable dirt were included that the trailer would have soon been filled. I then tried picking up the acorns as they lay on the ground and dropping them into a bucket. By this method, I was able to gather about 75 pounds of clean acorns per hour. After trying this method, I decided that a screen would be useful, so returned to Visalia where I purchased some one-half-inch-mesh hardware cloth and fastened it to a wooden frame 3 x 6 feet. I was unable to obtain larger wire for a second screen which would have enabled me to first separate the leaves and twigs from the acorns and dirt.

Using the above mentioned screen, I found that the acorns could be shoveled onto the screen from piles raked up under the trees. With a little shaking of the screen and agitating the material with the back of a rake, the dirt sifted through and the leaves and twigs piled up on top and were removed with a fork or by hand. Using this method, I found that I could harvest about 150 pounds of nearly clean acorns per hour.

As a result of these harvesting operations, I concluded that it would not be difficult to devise a light portable outfit consisting essentially of screens and a power blower by means of which the acorns could be quickly and efficiently separated in the field. It is hazardous to predict the amount of acorns that a man could harvest using a machine which has not been constructed, nevertheless, I believe that with some such equipment from

1500 to 2000 pounds of acorns per day could be harvested per man, including the time required to move from tree to tree and from one locality to another.

In order to gain an accurate figure as to production of acorns per tree, I selected one individual which was sufficiently isolated from its neighbors so that no mixing of acorns was possible. The tree selected was about 75 feet high, had a spread of nearly 100 feet and a trunk diameter of about 4 feet. The number of buckets of acorns harvested from this tree was recorded and one later weighed which gave a total production of over 500 pounds. The acorns of this tree were somewhat smaller than the average, so that larger trees with very large acorns are believed to produce more than twice this amount.

At the time I harvested the Valley Oak acorns, there were a few which had begun to germinate as a result of the light rains, and a few showed worm holes, but the bulk of the crop was in good condition and had not begun to rot or otherwise spoil.

In October and early November, 1944, I was able to examine trees of the Valley Oak over most of its range in California. The only area where I saw an abundance of acorns beneath the trees was in the vicinity of Clear Lake, Lake County. Beneath many of the trees in this area the acorns were as thick or thicker than at Cutler Park in 1943. I am sure that in the Clear Lake area harvesting would be as easy as at Cutler Park.

Processing and Storing

The acorns which were brought back to the Garden from Cutler Park were hauled in a metal-lined tightly-closed trailer and consisted of nearly two cubic yards of roughly cleaned material. When this was opened for unloading after having been closed almost continuously for several days, the surfaces of the acorns were wet, those in the center and bottom of the load slightly warm, and the walls of the trailer wet with moisture. All of these things indicated that spoilage could take place rather quickly unless the acorns were properly spread out to avoid heating and for drying.

These acorns were winnowed to remove the remaining leaves and other light material, after which they were cleaned by hand sorting, and spread out to dry in a layer about one foot deep on the concrete floor of an open shed and allowed to remain for several weeks. During this period, small fat grubs about $\frac{3}{8}$ inch long ate their way out of about 15 per cent of the acorns, after having consumed on an average about one-half of the meat of the acorn in which they had been.

After several weeks we found that under our conditions the acorns were drying very slowly and would apparently require several months to become sufficiently cured to be safely stored in large bins or sacked and piled. Perhaps the methods used in drying walnuts would be applicable here.

Grinding and rolling the acorns were considered as means of assuring rapid drying. Grinding appeared to offer complications for us in that the meal would require considerable attention to dry sufficiently without artificial heat, as well as incorporating all of the hulls with the ground kernels. However, as shown below, for whole dried acorns the fiber content is not excessively

FIGURE 10—The Sir Joseph Hooker Oak, a very noted specimen tree of *Quercus lobata*, growing a few miles east of Chico, Butte County, California. Photo, October 5, 1934. This tree has a north and south spread of 147 feet and a height of 101 feet. I estimated that in a good crop year this one tree produces from 1000 to 2000 pounds of acorns. In the Great Valley and in the Coast Ranges of California, there are hundreds of thousands of Valley Oaks over 75 feet in height and spread.

high, being exceeded by dried beet pulp, low protein cottonseed meal, whole oats, dried orange peel, and several other less known feeds.

Because of the limited amount of acorns which we desired to process, we did not feel justified in constructing a rolling machine. As a substitute, we spread out the acorns on a smooth cement floor and cracked or crushed them with an iron tamper such as is used for cement work. By this means, the hulls and kernels were left reasonably intact, and when thoroughly dried many of the hulls were removed by screening and most of the rest by hand. By this method, the finely powdered refuse from the wormy acorns was also easily screened out. These partially broken or half kernels appear to be as hard, or harder than well-dried flint corn and will probably keep indefinitely. Thoroughly dried kernels of this oak that have been kept in closed bottles as specimens in the Herbarium for more than ten years, are still firm and taste about like those freshly dried. It is our conclusion that a relatively simple mechanically operated roller could be constructed which would crush the acorns with much less power than would be required to grind them and would also make it easier to dry and store them, even though it might later be necessary to grind them before using as a feed.

During the summer of 1944, we discovered that the Valley Oak acorns, including the whole and crushed materials which were stored in a basement storeroom, were heavily infested with the larvæ of some sort of a moth. Through the courtesy of E. A. Dudley, Deputy Agricultural Commissioner of Orange County, we took the entire lot to the county's vacuum fumigator where methyl bromide gas appeared to kill all insects regardless of the stage of development. Mr. Dudley forwarded samples of the insects to the State Department of Agriculture where Mr. Keifer identified them as the Mediterranean Flour Moth (*Ephestia Kuehniella*), a common pest in flour and grain throughout the world. Mr. Dudley has since advised us that fumigations every few months are necessary for all grains in storage, and that acorns should also be considered in the same category.

After the methyl bromide fumigation of the acorn material, it was hand-screened, cleaned and stored in gunny sacks; and, at this writing, is still free from insect infestation.

The 1944 Valley Oak acorns which were collected near Clear Lake were fumigated for 24 hours with carbon disulphide in closed containers and then spread out to dry. This seems to have been effective in controlling the larvæ or grubs which are present in a small percentage of the acorns as harvested, and which eat a part of the kernel but do not seem to enter a second acorn. A few pounds of this lot of acorns were dried in an electric drying cabinet for several days at 100-110 degrees F. As a result of this method of drying, the kernels became darker than when dried at room temperature, and the tendency for the hull to split off from the kernel was more pronounced. By actual count, 26 per cent of the acorns were either completely or partially self-shelled. This feature suggests the possibility of experimenting with heat as a means of hulling, and it might well be that a method could be devised by which a much larger percentage would be self-hulled.

Additional tests of small lots of acorns of the Valley Oak were also carried on. A few pounds were hand-hulled and all wormy or inferior kernels discarded. These darkened considerably in drying. It was found that by boiling the kernels in several changes of water the bitterness (tannic acid) could be removed. However, the kernels turned nearly black. Soaking the kernels in a cold, one per cent lye solution for 24 hours, followed by a second similar soaking was also successful in removing the bitterness. Finely ground acorn meal was readily leached of its bitterness by allowing cold water to drip upon the meal placed in a large funnel on filter paper. The same result was accomplished by soaking the meal in several changes of cold water. Cooking the kernels or meal into a mush, such as the Indians prepared was tried, but our conclusion was that its flavor, although not disagreeable, was not sufficiently pleasant to appeal to the average American taste; and, for this reason, it is unlikely that acorn meal will ever again become an important source of human foodstuff.

As a stock feed, fresh Valley Oak acorns (Table 1) are over 40 per cent water and are low in proteins and fats, but when thoroughly air-dried have approximately the following composition:

Water	9	per cent
Protein	4.90	"
Fat	5.54	"
Fiber	9.46	"
Nitrogen-Free Extract (Carbohydrates)	69.02	"
Ash	2.08	"

Because of the low percentage of protein, they do not constitute a balanced ration and would have to be supplemented with other concentrates high in protein. For this reason, it appears that the principal value of Valley Oak acorns would be to farmers in the areas where the trees are native, and who could well afford to harvest and dry considerable amounts, since the harvesting and processing would be relatively inexpensive. Using Pacific Coast Barley for comparison, a hundred pounds has 81.6 pounds of proteins, carbohydrates and fats and, at present, costs $2.25 per 100 pounds wholesale. Dried Valley Oak acorns (with hulls) would have about 79 pounds of the same constituents and be worth approximately $2.18 per 100 pounds. On the same basis, the fresh acorns (40 per cent water content) would have nearly 52 pounds of dried food materials and be worth $1.43 per 100 pounds. Barley is said to yield as much as 3,000 pounds per acre, but the average for the United States is not much over 1,000 pounds (Morrison, page 347). Thus, using these figures, the value of barley per acre would range from $22.50 to $67.50. Dense stands of Valley Oaks in a good crop season might produce from 2,000 to 3,000 pounds of fresh acorns per acre with a value of $28.60 to $42.90. Even single large trees scattered over fields and producing around 500 pounds of fresh acorns would have crop values of $7.15 each, or a very large tree with 1,000 pounds of acorns a crop value of $14.30.

THE KELLOGG OAK

Figures 7, 11 & 12

The Kellogg Oak (*Quercus Kelloggii*) is the deciduous black oak so abundant in the mountains of southern California and in the Sierra Nevada. At these interior localities, it occurs at middle elevations largely in the Yellow Pine and Coulter Pine Forests. In the Coast Ranges it grows at lower elevations and is common from San Luis Obispo County northward but is much more abundant north of San Francisco. In the late fall its leaves turn bright yellow, or even reddish, at which time the tremendous numbers of trees of this species can be readily seen covering vast areas. Many of these trees are on steep hillsides and in rough ground, but they are also plentiful in open flats and gently rolling parts of the mountains where their acorns could be readily obtained.

Our field studies of the Kellogg Oak during 1943 were confined to the Sierra Nevada, in the vicinity of Bass Lake in Madera County, and the Cuyamaca Mountains in San Diego County.

In the vicinity of Bass Lake, and particularly on the gentle slopes surrounding the lake, the Kellogg Oak is an abundant tree. Many of the trees are 75 to 100 feet in height but have narrow crowns. On November 10 and 11, 1943, I collected acorns from trees in this area. At that time, all the acorns had fallen, there had been several rains, and they apparently had not dried out. No external indications of worm damage were noted, nor were any acorns already sprouted. The lack of fall germination is probably accounted for by the low temperatures.

Production of acorns by the Kellogg Oak did not appear to be as great per tree as for the Valley Oak; but, because of the narrow crown of the typical tree, they covered the ground nearly as thickly and could be raked up nearly as rapidly. Some trees produced exceptionally large acorns, many of which were found to weigh about one ounce each. I gathered about 250 pounds of Kellogg Oak acorns around Bass Lake which seemed sufficient for our tests.

On December 7 and 8, 1943, while in the mountains of San Diego County primarily for the purpose of studying *Quercus agrifolia* var. *oxyadenia* and collecting some of its acorns, I was enabled to observe a great many Kellogg Oaks. In the Cuyamaca Mountains, from Julian to Cuyamaca Lake and nearly to Descanso, the Kellogg Oak had produced a very large crop of acorns, and in many places the ground was thickly covered with them. Rain and snow hampered my observations, but I concluded that acorn production per tree in that area was as large as in the Bass Lake area. I later learned from Mr. Guy Fleming (Superintendent of California State Parks, Southern Division) that the Indians had been harvesting hundreds of pounds of Kellogg Oak acorns on Palomar Mountain and at Cuyamaca State Park for food. He also told me that he has often eaten acorn meal mush and has developed a fondness for it which others might also find acceptable. However, I did not see any indications that any of the crop had been harvested. Neither did I note that the squirrels, deer, other wild animals or birds and livestock had eaten

FIGURE 11—Explanation on opposite page.

or stored sufficient amounts of acorns to be noticeable. It was thus apparent, that in a season of good acorn production, that a large proportion of the crop remains on the ground to be eaten during the winter, spoil, or to germinate in the spring.

On November 25, 1944, I again visited the Cuyamaca Mountains of San Diego County, where I found that many of the Kellogg Oaks had again produced a fair crop of acorns, but in most instances not so large as in 1943. However, an important point to remember in this regard is that the Kellogg Oak apparently is a more regular producer of acorns than some of the other oaks.

My conclusion regarding the harvesting of Kellogg Oak acorns is that it could not be done on the large scale applicable to the Douglas and Valley Oaks, but that in many selected areas limited amounts (actually hundreds of tons) could be obtained by the same methods and with about the same effort.

Processing

A large part of the Kellogg Oak acorns was crushed in the same manner as those of the Valley Oak. Unfortunately, prolonged wet weather followed the operation; and, before I realized it, they had become covered with mold (*Penicillium sp.*) and had to be thrown away. A second portion was hand-hulled and the kernels dried without difficulty. The rest were allowed to remain in their shells and have dried very slowly but without spoiling.

The 1944 acorns gathered in the Cuyamaca Mountains were fumigated with carbon disulphide and spread out on the floor of the Herbarium to dry. They have dried rather slowly in the hulls and have not split open. Those dried similarly in 1943 are still keeping well.

Another observation, for which I have no exact figures, is that only a very small percentage of the acorns of the Kellogg Oak are wormy when harvested.

Feed Values

The acorns of the Kellogg Oak are richer than those of the Valley Oak and have noticeably oily kernels. However, the percentage of oil (13.55 per cent for fresh acorns or around 18 per cent for well dried acorns) is rather high, but not nearly as high as for *Quercus agrifolia* or var. *oxyadenia*. It is possibly too low to make it feasible to extract the oil. The fresh acorns contain nearly 10 per cent less water than those of the Valley Oak, but have a higher fiber content (8.60 per cent). They do, however, contain a greater total amount of proteins, fats and carbohydrates (Table 1).

Whole dried Kellogg Oak acorns would have approximately the following percentages of materials:

Water	9	per cent
Protein	4.56	"
Fats	17.97	"
Fiber	11.40	"
Carbohydrates	55.48	"
Ash	1.59	"

FIGURE 11—*Quercus Kelloggii* in the Sierra Nevada foothills near Plymouth, Amador County, California, September 23, 1933. The Kellogg Oak is characteristic of the Yellow Pine belt of California; but, as shown here, sometimes grows below the limits of that species. Its typical growth form is higher than broad.

Thus, 100 pounds of whole air-dried Kellogg Oak acorns would contain about 78 pounds of proteins, fats and carbohydrates and, in comparison with barley at $2.25 per 100 pounds, would be worth about $2.15 per cwt. On the same basis of comparison, 100 pounds of fresh acorns would contain about 59 pounds of the same ingredients and be worth $1.63 per cwt., although this might vary somewhat depending on the exact moisture content.

In general, the acorns of the Kellogg Oak would probably be used in much the same way for feed as those of the Valley Oak and would need to be supplemented with other concentrates high in protein. The high fat content (18 per cent) in the dried acorns might possibly be a disadvantage rather than an advantage, but this could only be determined by scientific feeding tests.

FIGURE 12—Acorns of *Quercus Kelloggii* as freshly gathered in the San Bernardino Mountains, San Bernardino County, California, October 22, 1931. Probably because of the low temperatures at the time the acorns of this oak fall to the ground, they remain in good condition for a long time and, apparently, do not germinate until the following spring.

THE COAST LIVE OAK

Figures 7, 13, 14, 15, 16 & 17

The Coast Live Oak (*Quercus agrifolia* and its variety *oxyadenia*) is an abundant tree from the San Francisco Bay Region southward in coastal regions to San Diego County and Baja California as far as the San Pedro Martir Mountains. North of San Francisco it is fairly common in Sonoma and Marin Counties but is rare northward in Mendocino County. For the most part, it is restricted to the valleys, canyons and slopes within 50 miles of the coast, and probably nowhere in California is found more than 100 miles inland. Over many of the areas where it grows, it is the most conspicuous tree, dotting the hillsides, forming great bands near water-courses and occasionally so abundant as to constitute small forests. The trees are especially conspicuous in summer and fall because of their dark green foliage which contrasts so strongly with the surrounding brown grasslands. Much of the native charm of the San Francisco Peninsula around San Mateo, Burlingame and Palo Alto, the country around Monterey, and the Santa Barbara region is due to the dominance of Coast Live Oaks.

In the Mountains of San Diego County, the Coast Live Oak is, perhaps, the most important tree up to elevations of 3,000 to 3,500 feet. However, these trees are slightly different in that the underside of the leaves is well-covered with hairs and are known as variety *oxyadenia*.

Quercus agrifolia, like other oaks, does not bear a crop of acorns every year, and 1943 was one of those seasons when practically no acorns were produced except on the trees of variety *oxyadenia* in San Diego County and adjacent Riverside County. Our observations on the acorn production of the Coast Live Oak have extended back over a considerable period of years, so that failure to produce a crop over most of its range in 1943 was not a serious handicap to our investigations.

The variation of conditions under which the Coast Live Oak grows is great. In many sheltered canyons, the accumulation of leaves and leafmold is several inches deep; and, as the acorns drop, many sink out of sight. In other areas the ground surface is relatively clean and the acorns form a carpet. On steep slopes the acorns often roll down hill and accumulate in large piles.

Coast Live Oak acorns are much smaller than those of the Valley Oak, the Blue Oak, or the Kellogg Oak; and, because of this, hand picking into a bucket is much slower, and not over 30 to 50 pounds of clean acorns can be harvested per hour. On the other hand, raking and screening offer no more complications than the species mentioned above except that a finer toothed rake and different screens would be necessary.

On December 7 and 8, 1943, I journeyed to the mountains of San Diego County to obtain acorns of *Quercus agrifolia* var. *oxyadenia* which I had been told, a few days previously, had produced a good crop in that region. According to my observation, the crop was not large; and, in many parts of the area, no acorns were produced at all. At Oakgrove there was a fair

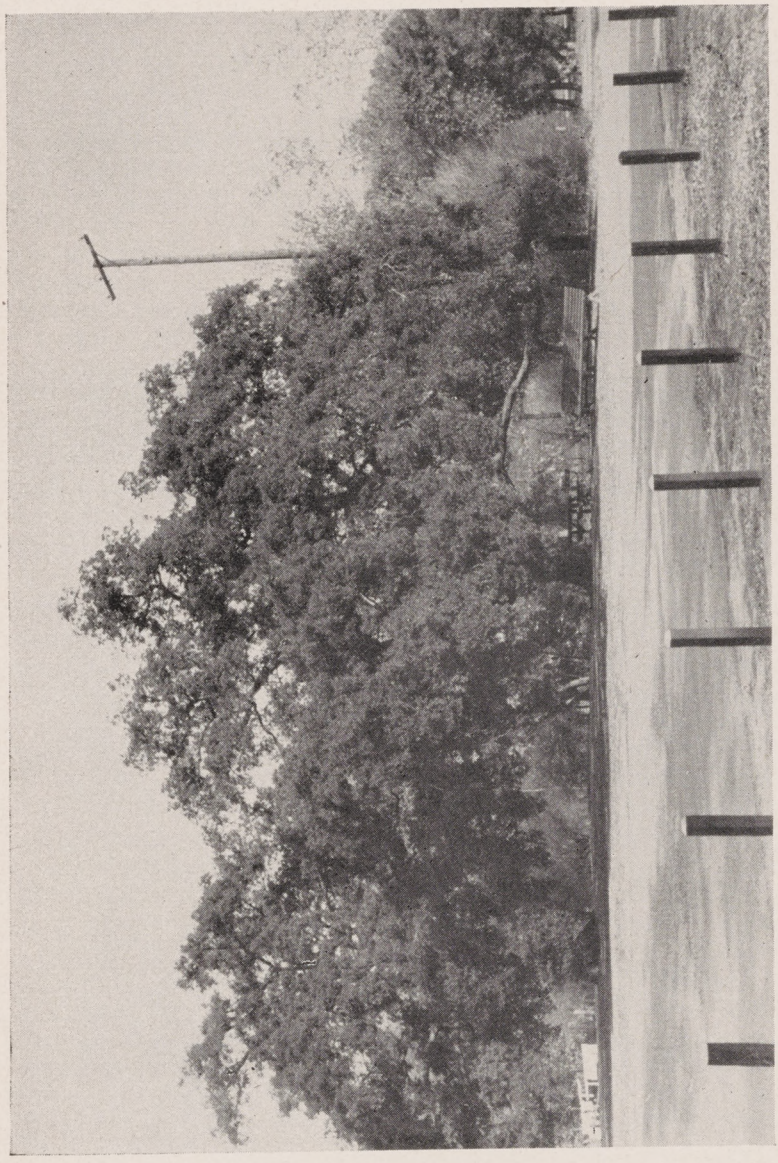

FIGURE 13—*Quercus agrifolia* at Orange County Park, Orange County, California. Photo, November 29, 1944. The large tree in the center of the picture is typical of hundreds of thousands of this species in California. It was estimated to be 70 feet high, 80 feet in spread and had a trunk over 4 feet in diameter. Several hundred pounds of acorns lay beneath this tree at the time the picture was taken.

crop, most of which was being raked up for stock feed. A local rancher was paying the school boys 30 cents per gunny sack for the acorns. Around Lake Henshaw and Descanso there were practically no acorns. At Guatay Mountain I found a few. East of Pine Valley at Kitchen Creek Forest Service Camp Ground were a few trees with a fair crop. Because of the limited crop and also because of rain and snow, I gathered only about 50 pounds of acorns. In 1944 there was practically no crop of acorns on the trees of variety *oxyadenia* in San Diego County.

In 1944 the Coast Live Oak again failed to produce a crop of acorns over most of its range, but in parts of southern California there were bumper crops. Beneath the trees in Ventura County, the ground was thickly carpeted as also in the Temescal Wash south of Corona, Riverside County. An extremely heavy crop of acorns was produced on the trees at Orange County Park, Orange County, where on November 29, 1944 I made a test harvest.

Orange County Park includes about 160 acres of land, of which the dominant tree is the Coast Live Oak. Perhaps 40 or 50 per cent of the total area is canopied by the crowns of the huge live oaks, many of which are over 75 feet high and have an even greater spread. On the basis of my observations, I have concluded that nearly 100 tons of acorns were produced at Orange County Park in 1944.

In order to obtain accurate data as to crop production, I made several tests at Orange County Park. One area of 500 square feet yielded 80 pounds of clean acorns. Other areas were even denser and averaged 175 acorns per square foot, or better than one pound per square foot. Even using the smaller of the above two figures, the crop of acorns produced by some of the larger trees runs into several hundred pounds. Using a steel-toothed leaf rake, I found that leaves and acorns could be quickly raked into piles that could be shoveled into the truck; and, in less than two hours of working by myself, I had filled the bed of the truck which when thoroughly cleaned yielded over 600 pounds of acorns. This load of acorns and trash, consisting mainly of leaves, was taken to G. E. Price of Santa Ana, who ran them through a large bean thresher in just a few minutes operation. Leaves, twigs and other light materials were readily separated from the acorns, but many of the acorn cups and small rocks could not be separated without modifying the machine. Mr. Price has granted me permission to quote him to the effect that he believes a small field threshing unit could be made-up on a two-wheel trailer. Such a unit could be taken almost anywhere and reasonably clean acorns sacked up regardless of how many leaves and other trash were mixed in originally.

Processing

Acorns of the Coast Live Oak were drier than the other kinds harvested and, perhaps for this reason, dried rather readily without molding or otherwise spoiling. A rather sizeable percentage of those which I had picked up were of poor quality when brought in, largely because they had been harvested late in the season and had been exposed to sun, rain and other influences which would spoil them. I suspect that greater care must be exercised in processing or storing the acorns of this species than with some

FIGURE 14—*Quercus agrifolia* at Orange County Park, Orange County, California. Photo, November 29, 1944. Note the orchard-like spacing in this natural grove which is so typical of thousands of similar areas of coastal California. The bulk of the material covering the ground consists of acorns.

other species because of the high oil content which apparently turns rancid rather easily. A few pounds of these acorns were hand-hulled, and their rich yellow kernels dried in the Herbarium, where thus far they have not turned rancid.

In drying these Live Oak acorns from Orange County Park, I discovered that adequate air circulation is more essential than high temperatures. Prompt fumigation with carbon disulphide resulted in killing practically all of the grubs which were active at the time of harvest.

Freshly gathered Coast Live Oak acorns (var. *oxyadenia*) tested 19.75 per cent moisture and 18 per cent fats, and 100 pounds would contain nearly 68.5 pounds of food materials which on the same basis of comparison as the other previously mentioned acorns would be worth about $1.88 (see Table 1). When thoroughly air-dried, the whole acorns would have approximately the following percentages of ingredients of which 77 pounds would be food materials and be worth $2.12 per cwt.:

Water	9	per cent
Protein	4.40	"
Fat	20.42	"
Fiber	11.68	"
Carbohydrates	52.74	"
Ash	1.76	"

As shown above, the high fat content of Coast Live Oak (var. *oxyadenia*) acorns would probably make them as undesirable as whole peanuts, soybeans or other fatty seeds as feeds for fattening swine. It is also probable that as a feed for other stock the high fat content would have a laxative effect even if it were not objectionable from the standpoint of producing "soft fat". However, if the bulk of this fat or oil should be extracted, there would remain an acorn oil meal which would not be objectionable from this standpoint.

A few ounces of Coast Live Oak (var. *oxyadenia*) acorn oil were extracted through the courtesy of the Glidden Company at the same time that the Joshua Tree oil was obtained. The freshly pressed oil was a rich, deep yellow in color, was somewhat thicker than olive oil, and had a rather pleasant and distinctive flavor. The small amount of oil remaining after the analysis had been made has gradually become somewhat stronger (slightly rancid) than when freshly pressed. The fresh oil made an excellent salad oil, but those who like a perfectly tasteless oil and do not care for olive oil, would probably not like it. Since the samples on which the above observations were based had not been purified, processed or treated in any way, there is little basis for suggesting that properly processed oil would not keep, or that its flavor could not be modified or removed almost entirely as is done with many edible oils.

The analysis of acorn oil (see Table 4) indicates that it is a non-drying oil, and that its characteristics are similar to olive oil. Its use would, therefore, appear to be as an edible salad oil or shortening.

Commercial extraction of acorn oil would offer no serious complications, since standard oil expellers could do the work with little modification. It has been estimated that a ton of fresh Coast Live Oak acorns would yield approximately 300 pounds of oil and a residue of acorn oil meal totaling over 1400 pounds (based on at least 10 per cent moisture), and which would have approximately the following analysis:

Water	10.00	per cent
Protein	5.40	"
Fat	4.00	"
Fiber	14.00	"
Carbohydrates	65.00	"
Ash	2.17	"

This acorn oil meal would contain about 75 pounds of food materials per 100 pounds and in comparison with barley (at $2.25 per 100 pounds) be worth about $2.07 per cwt., but would be much more comparable in the proportions of its ingredients to dried orange peel, except that it is somewhat lower in protein and higher in fat.

FIGURE 15—Acorns of *Quercus agrifolia* on the ground at Orange County Park, Orange County, California. This represents a typical area of level ground with the acorns undisturbed. The photo was taken November 29, 1944, at which time many acorns still remained on the trees.

On the above basis, a ton of fresh Live Oak acorns might yield the following:

300 pounds of oil at $.14 per pound[1]	$42.00
1400 pounds of acorn oil meal at $2.07 per cwt	28.98
Total Value	$70.98

From this figure it would be necessary to deduct the costs of processing the acorns to extract the oil, grind the meal, sack it, etc., which according to Mr. Barlow could be done for about $15.00 per ton. Even if the acorn

FIGURE 16—Acorns of *Quercus agrifolia* on level ground at Orange County Park, Orange County, California. Photo, November 29, 1944. Many acorns had not yet fallen from the trees so that the density would increase.

[1]Based on the oil being worth the same as cottonseed oil.

FIGURE 17—Acorns of *Quercus agrifolia* at Orange County Park, Orange County, California. Photo, November 29, 1944. The pile represents most of the acorns which had fallen on an area of approximately 500 square feet (20 x 25 feet). When these were thoroughly cleaned, over 80 pounds of acorns were obtained. The flat-toothed steel leaf rake shown is an effective instrument for harvesting.

oil meal should prove to be much less valuable than indicated above, it would probably yield enough to pay the costs of processing, so that the value of the oil would be sufficient to make it possible to pay from $30.00 to $35.00 per ton for acorns at the expeller plants. It would, therefore, appear that the harvesting of Coast Live Oak (var. *oxyadenia*) acorns could be a profitable venture, as well as providing a vast supply of good edible oil for which there may be a greater need as the war continues.

The ground acorn meal from which the oil has been pressed, in its untreated state, is a bitter, bran-like brownish material. Whether this bitterness (tannic acid) would be detrimental if the meal were used as stock food, has not been determined. However, soaking it in water for a couple of hours removed most of the bitterness. All bitterness was removed from small quantities placed on a filter paper in a funnel into which water dripped for two hours.

Quercus agrifolia acorns (1944 crop) from Orange County Park were sent to the Geo. W. Gooch Laboratories for analysis; and, as shown in Table 1, they are markedly different from those of variety *oxyadenia* from San Diego County. Whether this represents a uniform series of differences between the species and the variety, or whether it is merely a chance or local difference, I can not say. However, it would appear necessary to analyze numerous samples from throughout the ranges of the two oaks. As freshly gathered, the acorns from Orange County Park were much higher in moisture content and lower in fat than those from San Diego County. Even on a dry weight or air-dry basis, the former would be much lower in oil content and approach the proportions found in the Kellogg Oak. Thus, any definite efforts to extract oil from the acorns of *Quercus agrifolia* should be preceded by tests to determine the regions where acorns of highest oil content are produced.

The principal facts, observations and conclusions which I have presented in the foregoing account appertaining to the Coast Live Oak are as follows:

1). It is a widespread and abundant tree in the coastal regions of California from central California to San Diego County, ranging over thousands of square miles. The variety *oxyadenia* is confined largely to the interior of San Diego County and a portion of Riverside County.

2). Its periodic crops of acorns amount to thousands of tons (perhaps 100,000 tons) in a single season.

3). The acorns, although smaller than those of the Valley Oak, Blue Oak and Kellogg Oak, could be readily harvested with comparatively simple equipment.

4). Its acorns are probably the most valuable of all the oaks of California, not only because of their relatively large quantities, but because of the possibility of utilizing them for their high oil content.

5). Coast Live Oak acorn oil is a good quality edible oil, of which approximately 300 pounds could be obtained per ton of fresh acorns.

6). Acorn oil meal is somewhat like dried orange peel in its analysis but is lower in protein and higher in fats. As a stock feed, it might need

to be leached of its tannic acid for best results, a process which could readily be accomplished with cold water.

7). Provided that it should seem desirable to materially increase this country's supply of edible fats and oils either during the present war or in the future, it appears that the acorns of the Coast Live Oak offer a vast potential reservoir probably rivaled in California only by one other wild plant, the Joshua Tree.

8). The differences in oil content between acorns of *Quercus agrifolia* var. *oxyadenia* from San Diego County in 1943 and acorns of *Quercus agrifolia* from Orange County in 1944, suggest the necessity of extensive tests as to oil content of acorns from different regions throughout the range of the species and its variety.

THE GARRY OR OREGON OAK

Figure 8

The Garry or Oregon Oak (*Quercus Garryana*) is the common oak of the mountainous areas of northern California from parts of Sonoma and Lake Counties northward to Del Norte and Siskiyou Counties. It also grows northward through Oregon and Washington to British Columbia, but I am unfamiliar with it in those areas, except in very limited portions of southern Oregon.

In the coastal regions of northern California, the Garry Oak is a conspicuous tree in the areas commonly designated as "Bald Hills". These are generally open grassy hills, usually surrounded by Douglas-Fir forests, with Garry Oaks forming colonies over portions of these hills. Since these areas are the best sheep and cattle pastures of the region, the acorns contribute materially to the feed in good crop years. At the Blue Rock Ranch between Cummins and Bell Springs in northern Mendocino County, I learned on October 23, 1944 that when acorn crops are abundant, that the pigs, cattle and sheep first pick up the white oaks, in this case those of the Garry Oak, and leave those of the black oaks, *Quercus Wislizenii* and *Kelloggii,* until after the others are gone. I also learned that when exceptionally heavy crops of Garry Oak acorns are produced, that many of the local ranchers take their wagons; and, with scoop shovels and rakes, harvest the cream of the crop with little difficulty, mainly for feeding hogs. According to this same rancher, the Garry Oak makes a good grade of pork, whereas, when Black Oaks are eaten extensively, the pork is of poorer quality and is known as "soft pork". This is undoubtedly due to the high oil content of the acorns of the black oaks.

During October, 1944, I was able to observe the main areas of Garry Oak throughout northern California; but, unfortunately, in most places a very light crop of acorns was produced. However, between Weaverville and Redding I found an area where the Garry Oak was rather typical in its density and also had produced a fair crop. At this locality, the trees formed a rather open forest with annual grasses covering the ground. The trees ranged from 10 to 30 feet in height and from 10 to 25 feet in spread. Their trunks averaged 6 to 12 inches in diameter. Under many trees the ground was well covered with acorns. By hand-picking from off the ground, I found I could gather the acorns at the rate of 40 pounds per hour, which compared favorably with similar harvestings for other species. The rather short and thick acorns were remarkably free from worms and were also exceptionally sweet, perhaps as sweet, or at least less bitter, than any of the acorns of the other tree species discussed elsewhere in this paper. These rather small trees probably did not yield more than 10 to 20 pounds per tree in this area in 1944, but in a good season would likely produce at least twice this amount. However, the trees were close together and probably averaged 25 to the acre. This would indicate a production of 500 pounds per acre for 1944 and probably double this amount in a heavy crop year.

Northeast of Mount Shasta in the region east of Little Shasta Valley,

Siskiyou County, I also found a small area where the Garry Oak had produced a fair crop of acorns in 1944. One tree of about 25 feet in height and spread had produced an estimated 50 pounds of acorns.

Along the road from Redding to Alturas in the area near where Hat Creek flows into the Pit River, there are also extensive stands of Garry Oak, but in 1944 no crop was produced.

Closely related to the Garry Oak is Brewer Oak, *Quercus Breweri* or *Quercus Garryana* var. *Breweri*. This shrubby oak usually grows only 4 to 5 feet high and covers miles of hillsides in Shasta County. There are many such hillsides on the road from Weaverville to Redding and also on the upper Sacramento River in the vicinity of Shasta Dam. I was unable to discover any good acorns in these areas in 1944 but have seen them producing heavily in former years. I believe, that in seasons of heavy acorn production, the Brewer Oak probably produces larger amounts of acorns per acre than

FIGURE 18—Acorns of *Quercus Garryana semota* as freshly collected at Pineridge, Fresno County, California, September 20, 1933. Many botanists regard this variety as identical with *Quercus Garryana Breweri*, an abundant shrubby species of northern California. Like other scrub oaks, this one probably could not be harvested economically, even though it produces bumper crops of acorns.

the Garry Oak, but they could not be utilized except as they are picked up by stock and wild animals.

Another shrubby oak grows in the Southern Sierra Nevada foothills and is sometimes regarded as the same as the Brewer Oak. However, Professor Jepson named it *Quercus Garryana* var. *semota*. I know it best in the area between Tollhouse and Pineridge, Fresno County, where numerous hillsides are covered with it. Practically no crop was produced in 1944, so no data are available as to its true production, but many of the bushes were literally covered with hundreds of acorn cups from previous years. In 1933 there was an extremely heavy crop production in this area, at which time I collected acorns for propagation. I believe, this oak produces irregular bumper crops of the same amounts as Brewer Oak, but it would also not be feasible to attempt to harvest its acorns. It also is too limited in its distribution to be of more than very local interest. (Figure 18)

The acorns of the Garry Oak are rather typical of the other White Oaks discussed in this paper. That is, they are low in protein and fat but high in carbohydrates. One hundred pounds of freshly harvested Garry Oak acorns would contain nearly 59 pounds of proteins, fats and carbohydrates and would be worth $1.63 per cwt. in comparison with barley (at $2.25 per cwt.). Air-dried acorns would contain about 77 pounds of proteins, fats and carbohydrates and would be worth $2.12 per cwt.

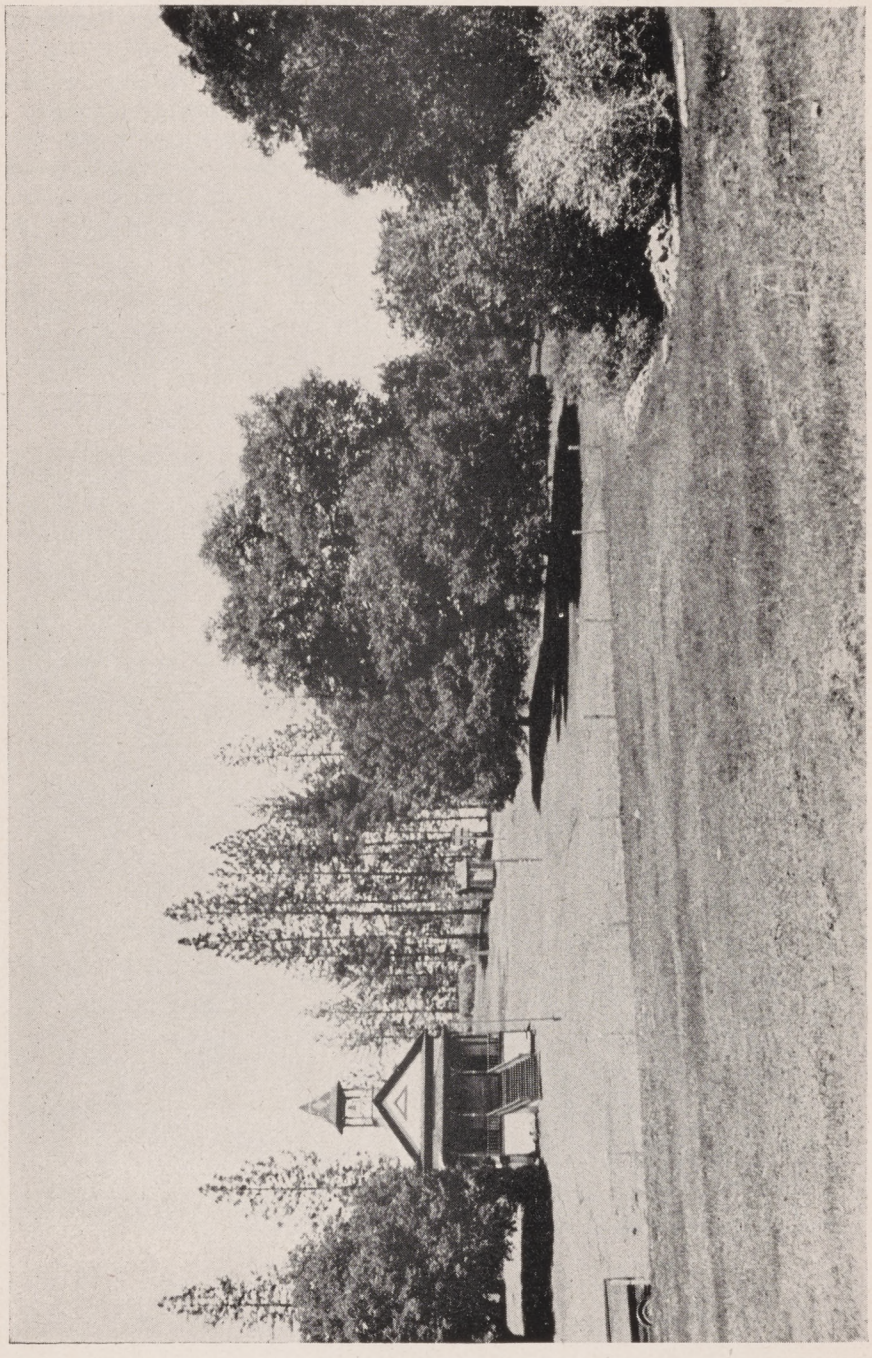

FIGURE 19.—Explanation on opposite page.

THE GOLDEN-CUP OR CANYON OAK

Figures 8, 19 & 20

The Golden-Cup or Canyon Oak (*Quercus chrysolepis*) is an abundant oak at middle elevations over much of California. It is one of the White Oaks, but unlike most of its relatives is an evergreen. In many areas trees of 75 feet high and a greater spread are common. In other less favorable situations, vast thickets of trees less than 25 feet in height are found. The acorns are extremely variable, even on adjacent trees, the largest known to me are from the Cuyamaca Mountains, San Diego County, which I believe are the largest produced by any oak in California and when first harvested weighed nearly an ounce each.

Under favorable conditions and in good crop years, the acorn production of this oak is as great or greater than that of the other tree species, but so many of the trees grow on such steep canyon slopes that harvesting the acorns would not be feasible. For these reasons, I am not giving any estimate as to the total tonnage produced, although I suspect it is about one-half that of the Kellogg Oak.

In 1943 I did not locate a single area where a heavy crop of acorns had been produced by the Golden-Cup Oak. On November 25, 1944, while in the Cuyamaca Mountains, San Diego County, I found that this oak had produced a huge crop. One tree along the road between Julian and Cuyamaca Lake was about 65 feet high, 80 feet in spread and had a trunk diameter of about 4 feet. The acorns lay on the ground so thickly that beneath the huge canopy I think nearly 50 per cent of the ground surface was covered. On the basis of a rather limited test pick, I estimated that this one tree produced well over 400 pounds of fresh acorns. I picked up nearly 75 pounds of clean acorns in about fifteen minutes, but believe that an hour's work with a rake would be sufficient to harvest the entire crop from beneath such a tree. It is of interest to note that the acorns of this oak fall to the ground while their hulls are still green. As a result, their water content is high, and they must be carefully dried to avoid spoilage.

The fresh acorns of the Golden-Cup Oak from the Cuyamaca Mountains showed 42.10 per cent water, the highest for any of the oaks thus far analyzed. They were extremely low in proteins but slightly higher in fats than some of the other White Oaks. Thus, freshly harvested Golden-Cup Oak acorns would contain a total of about 49 pounds of proteins, fats and carbohydrates per 100 pounds and be worth $1.35 per cwt. (compared to barley at $2.25 per cwt.). Air-dried acorns would contain 76 pounds of proteins, fats and carbohydrates and be worth $2.10 per cwt.

FIGURE 19—*Quercus chrysolepis Hansenii* at Pine Grove, Amador County, California, May 24, 1933. This variety probably is not really worth maintaining as distinct from typical *Quercus chrysolepis*. The large tree in the photo was about 60 feet in height and spread. Such large trees are abundant in the mountainous areas of California and frequently produce several hundred pounds of acorns in a single season. The trees in the background are Western Yellow Pine (*Pinus ponderosa*).

FIGURE 20—Acorns of *Quercus chrysolepis* as freshly gathered at Pineridge, Fresno County, California, September 20, 1933. These were not yet dropping and had to be hand-picked, hence the cups are still attached. In this species, the cups are often sulphur-yellow and are the basis for the common name, Golden-Cup Oak.

THE TAN-BARK-OAK

Figures 7 & 21

The Tan-Bark-Oak (*Lithocarpus densiflora*) is an important tree of the California Coast Ranges from the Santa Cruz Mountains northward to southern Oregon. It is comparatively rare south to Santa Barbara County and in the northern and central Sierra Nevada. It has long been an important source of tan-bark, obtained by cutting the trees, removing the bark and leaving the trunks to rot.

The large size of Tan-Bark-Oak acorns, as well as their great abundance and widespread geographic distribution, makes it essential to consider this species along with the oaks discussed above.

Because of transportation restrictions and lack of time, I did not attempt to study the Tan-Bark-Oak north of San Francisco Bay during the fall of 1943, but did manage to obtain a few pounds of acorns in the Santa Cruz Mountains a few miles back of Saratoga. I believe that in this latter area most of the Tan-Bark-Oaks grow on hillsides so steep that the collection of acorns would not be feasible.

On October 24, 1944, I gathered a few pounds of acorns of the Tan-Bark-Oak from along the Eel River in northern Mendocino County. No efforts were made to obtain large amounts, but a good crop lay on the ground, and I estimated that they could be harvested with about the same effort and as rapidly as the acorns of the Kellogg Oak. I also noted numerous other areas in coastal northern California where fair crops of Tan-Bark-Oak acorns had been produced. As a result of these observations in 1944, I believe that in good seasons the Tan-Bark-Oak produces acorns about as abundantly as the Kellogg Oak.

Tan-Bark-Oak acorns have thicker shells or hulls than any oak known to me and possibly because of this feature do not rot or spoil so quickly after falling. In comparison with acorns of the Kellogg Oak, our analysis (see Table 1) showed them to contain a little more water, nearly twice as much fiber (14.15 per cent), about two-thirds as much fat, and about the same proportion of protein. One hundred pounds of fresh Tan-Bark-Oak acorns would have 49 pounds of food materials worth about $1.35 per cwt. (as compared with barley at $2.25 per cwt.). When thoroughly dried, 100 pounds would contain about 69 pounds of food materials worth $1.90 per cwt., making them the least valuable of all the oaks discussed above. When thoroughly dry, the whole acorns would have approximately the following analysis:

Water	9	per cent
Protein	2.93	"
Fat	12.08	"
Fiber	20.14	"
Carbohydrates	54.43	"
Ask	1.42	"

FIGURE 21—Explanation on opposite page.

Tan-Bark-Oak acorns stored since 1943 are still in good condition. The kernels have shrunk considerably so that they lie loose in the rather hard shell. Because of this, I believe that a mechanical crusher would work to crack the hulls without injuring the meats, thus enabling easy separating. Hand-hulled meats stored in the Herbarium since 1943 are still in excellent condition; their oil has not turned rancid, and they have not been attacked by insects.

On the basis of the very limited information which I have regarding the Tan-Bark-Oak, harvesting its acorns as a livestock food would be practical only in areas where they were very easily obtained and only in seasons of prolific crops, because of their rather low food value and high fiber content. On the other hand, the individual acorns are large, facilitating harvesting, and their oil content would make them comparatively higher in net energy than the foregoing comparison would indicate. For these reasons, they might serve as a very useful feed concentrate if properly supplemented with proteins.

FIGURE 21—Tan-Bark-Oaks (*Lithocarpus densiflora*) along the old coast road four miles south of Honeydew, Humboldt County, California, October 29, 1930. Hundreds of square miles of the north Coast Ranges of California are covered with a forest consisting mainly of Tan-Bark-Oaks and Madrones (*Arbutus Menziesii*). The Tan-Bark-Oaks have long been cut solely for their bark; and, in many areas, few large individuals such as those shown here are left standing. In good crop years, the acorns cover the ground about as thickly as under the true oaks.

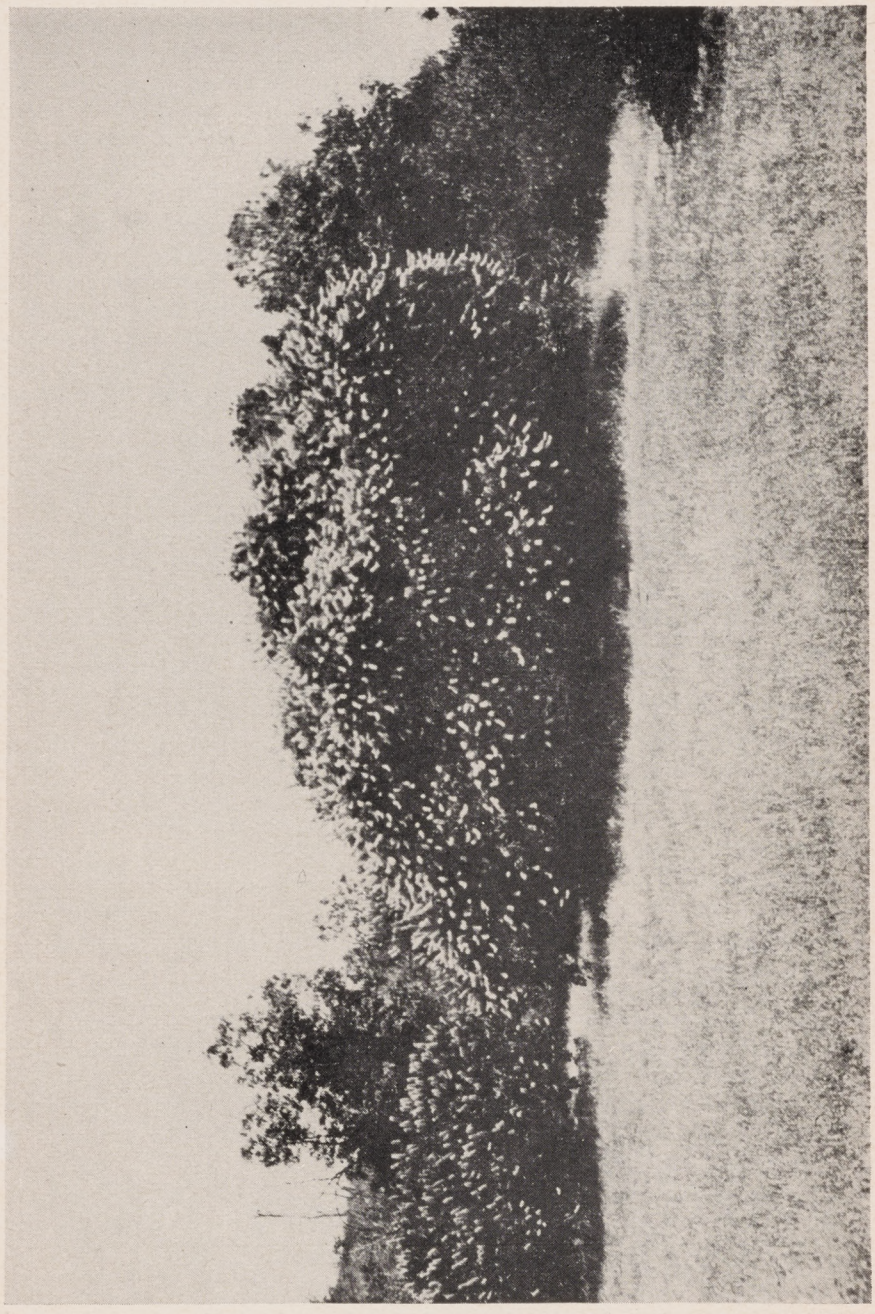

FIGURE 22—Explanation on opposite page.

THE CALIFORNIA BUCKEYE

Figures 22 - 25

The California Buckeye (*Aesculus californica*) is one of California's most curious trees as well as one of its most widespread. It ranges from northern Los Angeles County through the Coast Ranges and Sierra Nevada to Siskiyou and Humboldt Counties. In favored locations it often forms large stands, and northward sloping hillsides are frequently dominated by its somewhat shrub-like growth. Altogether, it ranges over a geographic area nearly as extensive as that occupied by the Blue Oak, and the number of Buckeye trees must total many millions.

These trees attract attention because they leaf out extremely early in the spring (often early in February), flower profusely in May and June, drop most of their leaves with the first hot weather of summer, and grow their fruits to maturity on usually bare branches. The fruits mature in November, usually hang by the thousands like Christmas tree ornaments, and soon split releasing the brown seeds, which are the largest of any native California plant. In seasons of large crops, these huge seeds practically cover the ground beneath the trees, or on steep slopes roll down hill and come to rest in piles.

Of the thousands of Buckeye fruits which I have examined, I have seen only a few that have been partially eaten by animals (squirrels, I think); all the rest seem to have been left strictly alone to rot during the winter or occasionally, if properly buried and kept continuously moist, to germinate in countless numbers where most of them do not survive the first dry summer season. Just how animals have learned to leave Buckeye fruits alone because of their poisonous nature (they contain an alkaloid *aesculin*) is of interest, for they certainly look appetizing with their smooth and shiny brown surface and nearly white, succulent, meaty cotyledons. However, I suspect that the extremely bitter flavor is sufficient to discourage most animals.

California Indians knew how to roast Buckeye fruits, remove the hulls and then leach out the bitter and poisonous properties with water. Experiments conducted by Professor M. E. Jaffa of the College of Agriculture of the University of California (Report of the Director, pp. 57-58. 1919) showed that Buckeye fruits could be dried, ground and then leached of their poison by soaking for 24 hours in one per cent lye solution. The resulting mash was then suitable as a poultry feed, but he did not suggest its use for human food. He also reported that Buckeye seeds were principally starch and water in about the same proportion as potatoes, or from two-thirds to three-fourths water. No further experiments on Buckeyes were ever reported by Professor Jaffa.

FIGURE 22—California Buckeye (*Aesculus californica*) in full bloom at Pine Grove, Amador County, California, July 1, 1933. This specimen was about 20 feet in height and had a spread of about 35 feet. The showy racemes of nearly white flowers number several thousand. Usually, only one to three fruits develop on each raceme. Shortly after flowering, the leaves usually drop, although the fruits do not mature until November. In a good crop year, such a tree produces well over 200 pounds of fresh fruits.

Temperton, mentioned earlier in this paper, has reported that poultry would not eat dry horse chestnuts (European species), but he was apparently unfamiliar with Professor Jaffa's lye leaching method.

Field Studies and Harvesting

Our principal field studies on the Buckeye were carried out in November, 1943, when we spent several days in the Santa Cruz Mountains and the Monterey region to determine something about the yield of fruits and the problems involved in harvesting them. At that time (November 14 - 18), it was found that only in a few of the driest localities had the Buckeye fruits dropped to the ground. However, the fruits were thoroughly ripe, many of the hulls were splitting and with very little shaking or knocking fell to the ground. Several hundred pounds were gathered at various places along

Figure 23—Fruiting California Buckeye (*Aesculus californica*) at Menlo Park, San Mateo County, California, November 13, 1934. This is one of the largest California Buckeyes observed and had a height of from 40 to 45 feet. At the time this picture was taken, about one-third to one-half of the rounded fruits had fallen to the ground.

Skyline Boulevard between the area back of Saratoga and the Woodside to La Honda road. Others were obtained in the vicinity of La Honda and along the coast from Pescadero to Santa Cruz. Later the Carmel Valley and the area between Monterey and Salinas were explored for Buckeyes, and the remaining capacity of the trailer filled with little effort.

In the Carmel Valley a typical large tree, having a height of about 25 feet and a spread of about 30 feet, produced over 200 pounds of fruits. I also found that because of the large size of the fruits, their heaviness and abundance, that it was not particularly difficult to pick up 200 pounds per hour. This figure, I believe, is probably the maximum that could be obtained as an hourly average, and I do not see how mechanical assistance could be of value, largely because of the undergrowth.

During the fall of 1944, additional field studies on the Buckeye were made. My general conclusion about crop production was that some trees which had borne a heavy crop in 1943 had a light crop in 1944. However, the sporadic or alternate crop production so characteristic of the oaks is not pronounced in the Buckeyes.

In many areas whole hillsides are dominated by the California Buckeye; and, under such conditions, I estimate that 8,000 to 10,000 pounds of fruits per acre are produced in a season. Although there is some variation in the size of crops, Buckeyes generally produce good-sized crops and do not have periodic seasons of huge crops followed by none, such as is characteristic of the Joshua Trees and the oaks.

Drying and Processing

Somewhat over 1,000 pounds of Buckeye fruits were brought back to the Garden and were spread out on the vacant benches of the glasshouse to dry. The hulls were still present on about one-half of the fruits and were removed by hand. Drying proved to be very slow, apparently because of the impervious nature of the brown seed coat and the very watery nature of the flesh. After several weeks it was found that many of the seeds were beginning to mold or rot on the inside, while still apparently good on the outside.

In an attempt to hasten drying, the entire lot of Buckeye seeds was crushed with an iron cement tamper, all obviously molded or rotten seeds removed, and then spread out in a large room to dry. Even by this method, mold and rot continued, and it was necessary to resort to drying in a cabinet using an electric heater and fan. After these were thoroughly dried, no further difficulty was encountered with mold or rot, and it appears that they could be stored indefinitely. During the year since these were dried, they have been kept in ordinary cloth sacks in a storeroom with no apparent spoilage or deterioration and no attacks from insects. In substantiation of this conclusion, Buckeye seeds collected in November, 1934, dried and then stored in a glass jar in the Herbarium were examined and found to be in as apparently good condition as those recently dried.

On November 3, 1944, I gathered a few pounds of Buckeye fruits from near Valley Springs in the central Sierra Nevada foothills. While these were still fresh, they were cut in half and dried at 100-110 degrees F. in an

electric drying cabinet for 72 hours. These dried seeds were then placed in sealed glass jars where they appear to be keeping perfectly.

The experience gained in handling these Buckeye seeds indicated that under ordinary conditions they are difficult to dry without spoilage.. Probably they could be much more successfully handled if they were ground when first harvested and spread out to dry or run through a dehydrator, but both of these processes would require considerable equipment and would not be feasible for farmers in the regions where Buckeyes are plentiful and could only be carried out if the Buckeye seeds or their products should prove to be of sufficient value to warrant hauling them to centrally located processing plants.

Feed Values

As shown by the analysis (see Table 1), fresh Buckeye seeds contain over two-thirds water, are very low in fiber, have practically no fat and less than 3 per cent protein. In other words, they are a very watery, starchy material, 100 pounds of which when first gathered would contain only about

Figure 24—Fresh fruits of *Aesculus californica* as knocked from a tree near Valley Springs, Calaveras County on November 3, 1944. These fruits normally drop from the trees late in November; and, for the most part, the hulls split off completely from the large shiny seeds.

32 pounds of food materials. Thus, 100 pounds of fresh Buckeye seeds would be worth $0.88 per cwt. using barley at $2.25 per 100 pounds as a basis of comparison. Dried Buckeye seeds would have approximately the following analysis:

Water	9	per cent
Protein	7.42	"
Fats	1.16	"
Fiber	4.50	"
Nitrogen-Free Extract (Carbohydrates)	74.44	"
Ash	3.48	"

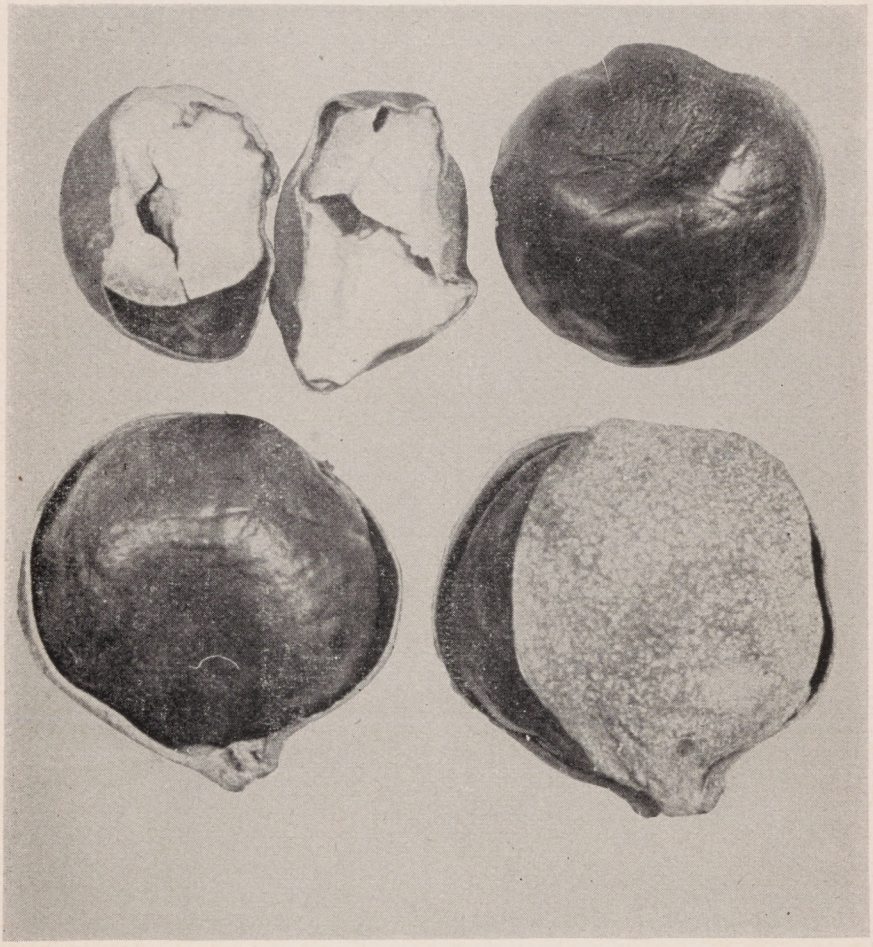

FIGURE 25—Fruits of *Aesculus californica* slightly reduced. These are from Valley Springs, Calaveras County, California and were collected November 3, 1944. Top left are thoroughly dried half fruits; the rest are partially dried. The whole seed in the upper right corner was two inches in diameter when photographed.

Thus, on the same basis of comparison as above, 100 pounds of dried Buckeye seeds would contain 83 pounds of proteins, fats and carbohydrates and be worth about $2.29 per cwt. This dried material does not differ greatly in the proportions of its proteins, fats, and carbohydrates from Pacific Coast Barley. On the above basis, a dense stand of Buckeyes in a good season, yielding 8,000 pounds of seed per acre, would have a value of about $70.40.

Conclusions

1). That the Buckeye, which is not only widespread and abundant but also a prolific producer of large seeds, is a potential source of vast amounts of feedstuffs.

2). That harvesting operations would probably be confined to picking up the seeds by hand, the maximum rate of which would be about 200 pounds per hour per man.

3). That drying the seeds is not easy or successful under ordinary conditions, and that driers or dehydrators would be necessary to insure proper results.

4). That the removal of the poisonous alkaloid principle (*aesculin*) could be accomplished by soaking the ground mash in a one per cent lye solution, as suggested by Professor Jaffa, and should probably be done in connection with grinding and drying.

5). That despite the watery nature of the fresh seeds, dried Buckeye seed mash has a relatively high value and is comparable in the proportion of its ingredients to Pacific Coast Barley.

6). That when converted into feedstuffs, the 8,000 pounds per acre of the Buckeye seeds from dense stands would have a value of $70.40, using as a basis of comparison Pacific Coast Barley at a price of $2.25 per 100 pounds, and that California has hundreds of thousands of hillside acres now covered with Buckeye yielding crops of this size, all of which are wasted and which it seems a shame to ignore because it is unlikely that much of the land they occupy could be utilized for other crops.

7). That investigations are desirable as to the possibilities of utilizing the high carbohydrate content of the Buckeye fruits in some commercial process such as the production of alcohol or pastes where the poisonous alkaloid would not be objectionable and might even be desirable.

TABLE 1 ANALYSES OF IMPORTANT CALIFORNIA WILD TREE CROPS[1]

Name, Year Harvested, and Locality	Condition of Material	Proximate Percentages of Chemical Composition						Total pounds Proteins, Fats and Carbohydrates per cwt.	Per Cent Value Comparison with Barley[2]	Monetary value with Barley at $2.25 per cwt.
		Water	Protein (N.x 6.25)	Fats	Fiber	Nitrogen-Free Extract (Carbohydrates)	Ash (Mineral Matter)			
Aesculus californica	as harvested	64.70	2.88	0.45	1.75	28.87	1.35	32	39	$0.88
Crop 1943	air-dry storage	9.0	7.42	1.16	4.50	74.44	3.48	83	102	$2.29
Carmel Valley	dry basis		8.16	1.28	4.96	81.77	3.83	91		
Lithocarpus densiflora	as harvested	36.00	2.06	8.50	14.15	38.29	1.00	49	60	$1.35
Crop 1943	air-dry storage	9.0	2.93	12.08	20.14	54.43	1.42	69	84	$1.90
Saratoga, Santa Cruz Mountains	dry basis		3.22	13.28	22.12	59.82	1.56	76		
Quercus agrifolia	as harvested	29.10	4.88	13.05	9.05	42.52	1.40	60	73	$1.65
Crop 1944	air-dry storage	9.0	6.26	16.75	11.62	54.57	1.80	77	94	$2.12
Orange County Park	dry basis		6.89	18.42	12.77	59.94	1.98	85		
Quercus agrifolia oxyadenia	as harvested	19.75	3.88	18.00	10.30	46.52	1.55	68	83	$1.88
Crop 1943	air-dry storage	9.0	4.40	20.42	11.68	52.74	1.76	77	94	$2.12
Kitchen Creek, S. D. Co.	dry basis		4.84	22.44	12.84	57.95	1.93	85		
Quercus chrysolepis	as harvested	42.10	2.63	5.50	8.10	40.42	1.25	49	60	$1.35
Crop 1944	air-dry storage	9.0	4.13	8.65	12.73	63.52	1.97	76	93	$2.10
Cuyamaca Mountains	dry basis		4.54	9.49	13.98	69.83	2.16	84		

TABLE 1—Continued

Quercus Douglasii		as harvested	33.60	4.00	5.90	7.15	47.80	1.55	58	71	$1.60
Crop 1944		air-dry storage	9.0	5.48	8.09	9.80	65.50	2.13	79	96	$2.18
Red Bluff		dry basis		6.03	8.88	10.76	72.00	2.33	77		
Quercus Garryana		as harvested	30.70	3.00	3.40	9.10	52.45	1.35	59	72	$1.63
Crop 1944		air-dry storage	9.0	3.94	4.47	11.95	68.87	1.77	77	94	$2.12
Weaverville		dry basis		4.33	4.91	13.13	75.68	1.95	85		
Quercus Kelloggii		as harvested	31.40	3.44	13.55	8.60	41.81	1.20	59	72	$1.63
Crop 1943		air-dry storage	9.0	4.56	17.97	11.40	55.48	1.59	78	95	$2.15
Bass Lake		dry basis		5.02	19.76	12.53	60.94	1.75	86		
Quercus lobata		as harvested	40.80	3.19	3.60	6.15	44.91	1.35	52	63	$1.43
Crop 1943		air-dry storage	9.0	4.90	5.54	9.46	69.02	2.08	79	96	$2.18
Cutler Park		dry basis		5.39	6.08	10.38	75.87	2.28	87		
	Whole Pods	as harvested	6.40	7.19	17.25	15.10	50.46	3.60	76	93	$2.10
		air-dry storage	9.0	7.00	16.78	14.69	49.04	3.49	73	89	$2.01
		dry basis		7.68	18.45	16.15	53.88	3.84	80		
Yucca brevifolia	Pods Only	as harvested	7.60	6.69	2.00	16.85	59.96	6.90	68	83	$1.88
var. *Jaegeriana*		air-dry storage	9.0	6.60	1.96	16.60	59.06	6.78	67	82	$1.85
Crop 1943		dry basis		7.24	2.16	18.24	64.90	7.46	74		
Cima	Seeds Only	as harvested	5.90	10.56	34.40	10.45	37.04	1.65	82	100	$2.26
		air-dry storage	9.0	10.20	33.28	10.11	35.82	1.59	79	96	$2.18
		dry basis		11.21	36.57	11.10	39.37	1.75	87		
Barley -		as harvested									
Pacific Coast[2]		air-dry storage	10.10	8.70	1.90	5.70	71.00	2.60	81.6	100	$2.25
		moisture free		9.67	2.12	6.35	78.96	2.90	91		

[1] and [2]—See bottom of page 64.

TABLE 2

MOISTURE DETERMINATIONS ON SOME STORED SEEDS[3]

Name	Moisture
Aesculus californica 1943 Crop Stored Room Temperature	10.20 per cent
Quercus agrifolia oxyadenia 1943 Crop Stored Room Temperature	7.30 "
Quercus Kelloggii 1943 Crop Stored Room Temperature	7.80 "
Quercus lobata 1943 Crop Stored Room Temperature	9.50 "
Lithocarpus densiflora 1943 Crop Stored Room Temperature	8.30 "

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[1]This Table presents analyses of ten California wild tree crops. The figures presented for the seeds or fruits "as harvested" are from analyses made by the Geo. W. Gooch Laboratories. Those for "air-dry storage" are computed from information obtained on tests reported on Table 2. The arbitrary figure of 9 per cent moisture content for all the products was selected upon the recommendation of Mr. W. F. Beedle. The figures on a "dry basis" were also largely computed by Mr. Beedle and serve as a definite means of comparing proportions of dry matter. The figures for Pacific Coast Barley are included so as to more vividly enable a comparison with a common feedstuff of this region. Other values and percentages would be obtained if the proteins, fats and carbohydrates were to be figured on three different value scales, but for the purposes of this paper the single computation seems to be satisfactory. However, in the case of the oaks with high oil content and the Joshua Tree seeds, the values are, therefore, much too low if the oil is to be extracted. It is of particular interest to note in connection with the several oaks tested that on a 9 per cent moisture basis, with the exception of the Tan-Bark-Oak, they all are above 90 per cent as high in total proteins, fats and carbohydrates as barley. The basis for computing values in dollars in comparison with Pacific Coast Barley has been explained previously (page 15. Morrison's analysis of Pacific Coast Barley was selected because it was slightly higher than numerous others consulted. Accordingly, the figures for the acorns and other products would be slightly more conservative.

[2]Pacific Coast Barley on air-dry storage basis is from Morrison (Feeds and Feeding, p. 976. 1943). Other analyses show slightly lower feed values, i.e., E. H. Hughes, Barley a Feed for Hogs, (University of California College of Agriculture Circular **343**, page 2. 1937) —

Dry Matter	Protein	Fat	Fiber	Nitrogen-Free Extract (Carbohydrates)	Mineral Matter
89.8	9.5	1.9	6.1	69.6	2.7

[3]These samples were from the same lots of materials as those tested in 1943 and had been in storage at room temperature for over a year. The moisture determinations were made at the Geo. W. Gooch Laboratories, December, 1944. On the basis of these moisture percentages, Mr. Beedle suggested using 9 per cent moisture for all of the materials, since the moisture would likely vary considerably at different times of the year and in different climatic regions.

TABLE 3

PERCENTAGES OF MEATS AND HULLS BASED ON HAND-HULLED SAMPLES JANUARY, 1945[1]

	Per cent Meat or Kernel	Per cent Hull	Remarks
Aesculus californica 1943 Crop Carmel Valley, Monterey County	70	30	difficult to separate hulls or seed coats from meats.
Aesculus californica 1944 Crop Sierra Nevada foothills	72	28	dried at 100°-110° F. then stored at room temperature.
Lithocarpus densiflora 1943 Crop Saratoga, Santa Cruz Mountains	60	40	hulls hard, can be cracked like filberts
Quercus agrifolia 1944 Crop Orange County Park	78	22	not yet completely dry, thus percentage of meats too high.
Quercus agrifolia oxyadenia 1943 Crop Kitchen Creek, San Diego County	72	28	
Quercus chrysolepis 1944 Crop Cuyamaca Mountains, San Diego County	76	24	not yet completely dry, thus percentage of meats too high.
Quercus chrysolepis Hansenii 1944 Crop Pine Grove, Amador County	72	28	
Quercus Douglasii 1944 Red Bluff, Sacramento Valley	74	26	
Quercus dumosa 1927 Crop San Bernardino Mountains	74	26	meats apparently in good condition although stored for 17 years.
Quercus dumosa 1930 Crop Lake County	76	24	meats apparently in good condition although stored for 14 years.
Quercus durata 1944 Crop Knoxville, Napa County	72	28	
Quercus Engelmannii 1944 Crop Santa Ysabel, San Diego County	90	10	meats still very moist so this figure not at all accurate.

[1]—See bottom of page 67.

TABLE 3 (Cont.)

	Per cent Meat or Kernel	Per cent Hull	Remarks
Quercus Garryana 1944 Crop Weaverville, Trinity County	76 74	24 26	dried at room temperature. dried at 100°-110° F. 72 hours.
Quercus Kelloggii 1931 Crop Bear Valley Dam, San Bernardino Mts.	70	30	meats apparently in good condition although stored for 13 years.
Quercus Kelloggii 1943 Crop Bass Lake, Madera County	74	26	
Quercus Kelloggii 1944 Crop Cuyamaca Mts., San Diego County	74	26	
Quercus lobata 1943 Crop Cutler Park, Tulare County	74	26	
Quercus lobata 1943 Crop Lebec, Kern County	75	25	
Quercus lobata 1944 Crop Clear Lake, Lake County	78	22	room-dry, but incompletely so.
Quercus lobata 1944 Crop Clear Lake, Lake County	74	26	dried for 4 days at 100°-110° F., 26 per cent of acorns split their hulls.
Quercus Palmeri 1943 Crop Boulevard, San Diego County	58	42	hulls extremely thick and woody.
Quercus Wislizenii 1930 Crop Calpella, Mendocino County	76	24	meats apparently in good condition although stored for 14 years.
Quercus Wislizenii frutescens 1939 Crop Liebre Mts., Los Angeles County	72	28	meats apparently in good condition although stored for 5 years.
Quercus Wislizenii frutescens 1944 Crop Ione, Amador County	70	30	very slender acorns; these apparently well-dried at this time.
Yucca brevifolia 1943 Crop Hesperia, San Bernardino County	57	43	hulls are really the pods or capsules and are not waste; meats are the black seeds which can not readily be shelled.

TABLE 4

OIL ANALYSES[2]

	Quercus agrifolia var. oxyadenia	Yucca brevifolia var. Jaegeriana
Specific Gravity at 15°/15°C.	0.9170	0.9224
Refractive Index at 17°C.	1.4709	1.4739
Free Fatty Acids (As Oleic)	0.50 per cent	2.10 per cent
Iodine Number (Wijs)	90.5	120.3
Saponification Number	192.3	192.5
Unsaponifiable Matter	1.46 per cent	0.65 per cent
Titer	25.3°C.	10.6°C.

[1]Samples of all of the materials which were analyzed were used to make the tests as to percentages of hulls and meats. Several other species were also included, and the samples were largely from collections stored in the Herbarium. With a few exceptions, these were 50 gram samples and were carefully hand-hulled. It will be noted that most of the acorns have over 70 per cent of meats. King and McClure, in their paper in the Journal of Agricultural Research which has been previously referred to, reported that the Willow Oak (*Quercus phellos*) had 69.92 per cent of kernel. Their analyses showed that the bulk of the fiber was in the shell, the fat was almost entirely confined to the kernel, but that the proteins and starches were not so exclusive. However, if an efficient method could be devised for hulling acorns, the resulting kernels or meats might prove to be so much richer in food materials and so much better as feedstuffs that many of the objections to acorns as starch food would be eliminated. For example, the acorns of the Valley Oak (*Quercus lobata*) on an air-dry basis have 9.46 per cent fiber, and the hulls constitute about 25 per cent. Accordingly, the kernels or meats would probably only contain one or two per cent fiber and would be proportionately higher in other constituents.

[2]Above analyses were made in 1944 by the Geo. W. Gooch Laboratories, Ltd., Los Angeles, California, and certified by R. S. Huffman. These may be compared readily with a similar analyses as found in Jamieson (Vegetable Fats and Oils) or other works on vegetable oils. It would be of interest, or as necessary, to similarly test the oils from *Quercus agrifolia* and *Kelloggii*, particularly if commercial utilization were contemplated, but we did not have this done because we felt it was an unnecessary additional expense.

SUMMARY

Investigations as to crop production, probable values and possible utilization of a number of wild tree crops of California have been carried on during the past two years by Rancho Santa Ana Botanic Garden. The important trees which were included in these studies were: The California Buckeye, *Aesculus californica* Nutt.; the Tan-Bark-Oak, *Lithocarpus densiflora* (Hook. and Arn.) Rehd.; the Coast Live Oak or Encina, *Quercus agrifolia* Nee and variety *oxyadenia* (Torr.) J. T. Howell; the Golden-Cup or Canyon Oak, *Quercus chrysolepis* Liebm.; the Blue or Douglas Oak, *Quercus Douglasii* Hook. and Arn.; the Garry or Oregon Oak, *Quercus Garryana* Dougl.; the Kellogg or California Black Oak, *Quercus Kelloggii* Newb.; the Roble or Valley Oak, *Quercus lobata* Nee; and the Joshua Trees, *Yucca brevifolia* Engelm. and variety *Jaegeriana* McKelv.

From these investigations, it has been possible to present considerable information as to the frequency and amounts of crops produced. Limited harvesting operations have provided a first-hand basis for arriving at estimates as to the ease or difficulty of harvesting, and for making suggestions as to how commercial or large-scale harvesting might be accomplished. Analyses of the seeds or fruits have demonstrated the potential feed values of these numerous wild crops and have provided a basis for more or less direct comparisons with standard feedstuffs. Drying and storage of the limited quantities of materials which were harvested have been mainly satisfactorily carried out but have demonstrated that many problems along these lines need to be solved. Most of the seeds or fruits investigated appear to be most valuable as sources of high carbohydrate feedstuffs for stock, or perhaps for industrial uses, and are not likely to be of any significance for human food. However, the acorns of the Coast Live Oak, the Kellogg Oak and the seeds of the Joshua Trees are high in good quality edible oils and are thus potential sources of thousands of tons of human food.

Feeding tests, large-scale harvesting operations or commercial exploitation of these several tree crops are not within the scope of activity of Rancho Santa Ana Botanic Garden; and will therefore, need to be carried out by other institutions or commercial organizations who are equipped for such work.

The principal value of the present studies lies in directing attention to the large wild tree crops of California which in the aggregate represent several million tons per year, but which are at present largely wasted.

INDEX

Aesculin 55, 60
Aesculus californica 1, 54, 55, 56, 58, 59, 62, 64, 65, 68
Alcohol 60
Alkaloid 55, 60
Analyses 13, 30 33, 39, 40, 51, 59, 62, 63
Arbutus Menziesii 53
Barley 62
Pacific Coast.... 15, 30, 60, 63 64
Production in California.... 25
Barlow, Lyman 2, 13
Beetle, W. F. 2, 64
Buckeye, California.... 1, 3, 55, 56, 68
Carbon disulphide 29, 33
Carob 3
Castanopsis chrysophylla 1
Cherry, Western Choke 1
Chestnut 3
Horse 4, 56
Chinquapin 1
Corn 3
Corylus rostrata var. *Californica*.... 1
var. *Traceyi*..... 1
Crops, Acorn 1
Dehydrator 58
Drying Cabinet, Electric..... 29, 58
Dudley, E. A 29
Encina 68
Ephestia Kuehniellia 29
Feed, Poultry 55
Ferris, G. F. 1
Fleming, Guy 31
Fumigation, Vacuum 29
Geo. W. Gooch Laboratories..... 2, 64, 67
Glidden Company 2, 39
Graham 9
Hughes, E. H. 64
Hutchins, W. D. 4
Indians 3, 15, 30
California 19, 55
Insects 57
Iodine Number 15, 67
Jaffa, M. E. 3, 55, 60
Jamieson, George S. 4, 67
Jepson, W. L. 2
Joshua Tree 1, 5, 10, 11, 15, 16, 64, 68
Juglans californica 1
Hindsii 1
King and McClure 67
King, Thomas R. 4
Keifer 29
Lithocarpus densiflora 20, 21, 51, 52, 62, 64, 65, 68
Locust 3
Lye solution 30, 55, 60
Madrones 53
McClure, Harold E. 4
Meal, Acorn 30
Acorn Oil 40, 41
Alfalfa-leaf 4
Citrus 2
Joshua Tree Seed..... 13
Merriam, C. H. 3, 19
Mesquite 1, 3
Metcalf, Woodbridge 23
Methyl Bromide 29
Moisture Determinations 64
Mold 33, 57
Morrison, F. B..... 4, 64
Moth, Mediterranean Flour..... 29

Mush 30
Acorn Meal 31
Nuts, Hazel 1
Oil, Acorn 39, 40, 41
Analyses 67
Joshua Tree 39
Olive 39
Salad 39
Vegetable 67
Oaks 3
Blue ..19, 21, 23, 24, 35, 55, 68
Brewer 46, 47
California Black 3, 68
California White 3
Canyon 49, 68
Coast Live....21, 35, 37, 39, 68
Douglas 23, 68
Engelmann 21
Garry 45, 47, 68
Golden-Cup 49, 68
Kellogg..19, 21, 31, 32, 33, 34, 35, 43, 49, 51, 68
Oregon 45, 68
Post 4
Red 4
Roble 21, 26, 68
Sierra Live 21
Sir Joseph Hooker 21, 28
Tan-Bark....21, 51, 52, 53, 64, 68
Valley 21, 25, 26, 27, 28, 29, 30, 33, 34, 35, 67, 68
Willow 67
White 4, 49
Paste 60
Peel, Dried Orange 40
Penicillium 33
Percentages of Meats and Hulls 65, 66
Persimmon 3
Pine Digger 1
Piñon 1
Sugar 1
Western Yellow 49
Pinus Lambertiana 1
monophylla 1
ponderosa 49
Sabiniana 1
Poisonous Properties 55
Pork 45
Potatoes 55
Poultry 56
Rations 4
Price, G. E. 2, 37
Prosopis chilensis 1
pubescens 1
Prunus demissa 1
Quercus agrifolia 20, 21, 35, 36, 38, 40, 41, 42, 43, 62, 65, 67, 68
var. *oxyadenia* 20, 21, 31, 35, 37, 39, 62, 64, 65, 67, 68
Breweri 46
chrysolepsis 22, 49, 50, 62, 65, 68
var. *Hansenii*....48, 49, 65
Douglasii 4, 19, 21, 22, 23, 24, 63, 65, 68
dumosa 65
durata 65
Engelmannii 21, 65
Garryana 22, 45, 63, 66, 68
var. *Breweri* 46
var. *semota* 46, 47
Kelloggii 3, 20, 21, 31, 32, 34, 45, 63, 64, 66, 67, 68
lobata 3, 4, 21, 22, 26, 28, 63, 64, 66, 67, 68
Palmeri 66
palustris 4
phellos 67

Wislizenii 21, 45, 66
var. *frutescens* 66
Refractive Index 67
Rot 57
Saponification Number 67
Seed, Cotton 13
Flax 13
Shortening 39
Smith, J. Russel 3
Soybeans 13
Specific Gravity 67
Squirrels 55
Starch 55
Tannic Acid 30
Titer 67
Temperton 4, 56
Thresher, Bean 37
Titus 4
Unsaponifiable Matter 67
Values, Monetary 13, 15, 16, 25, 30, 34, 39, 40, 41, 43, 47, 49, 51, 59, 60, 62, 63, 64
Vitamin A 4
Waldo 2
Walnuts, Black 1
Webber, H. J. 2
Wheat Bran 13
Yucca arborescens 5
brevifolia 1, 5, 6, 7, 8, 9, 12, 14, 16, 66, 68
var. *Jaegeriana* 1, 5, 7, 8, 9, 10, 16, 63, 67, 68
var. *Wolfei* 5
Draconis var. *arborescens*.....5
schidigera 8, 15, 17, 18
Yucca, Mojave 8, 15, 17, 18

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